Art, Design and Science, Engineering and Medicine Frontier Collaborations: Ideation, Translation, Realization: Seed Idea Group Summaries

DETAILS

120 pages | 6 x 9 | PAPERBACK
ISBN 978-0-309-44347-0 | DOI: 10.17226/23528

AUTHORS

The National Academies Keck Futures Initiative

THE NATIONAL ACADEMIES
KECK FUTURES INITIATIVE

Art, Design and Science, Engineering and Medicine Frontier Collaborations

Ideation, Translation, Realization

Seed Idea Group Summaries

Conference
Arnold and Mabel Beckman Center
Irvine, California
November 12-13, 2015

THE NATIONAL ACADEMIES PRESS
Washington, DC
www.nap.edu

THE NATIONAL ACADEMIES PRESS 500 Fifth Street, NW Washington, DC 20001

NOTICE: The Seed Idea Group summaries in this publication are based on Seed Idea Group discussions during the National Academies Keck *Futures Initiative* Conference on Art, Design and Science, Engineering and Medicine Frontier Collaborations: Ideation, Translation, and Realization held at the Arnold and Mabel Beckman Center in Irvine, California, November 12-14, 2015. The discussions in these groups were summarized by the authors. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the Seed Idea Group and do not necessarily reflect the view of any organization or agency that provided support for this project. For more information on the National Academies Keck *Futures Initiative* visit www.keckfutures.org.

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International Standard Book Number-13: 978-0-309-44347-0
International Standard Book Number-10: 0-309-44347-4
Digital Object Identifier: 10.17226/23528

Additional copies of this report are available from the National Academies Press, 500 Fifth Street, NW, Keck 360, Washington, DC 20001; (800) 624-6242 or (202) 334-3313; http://www.nap.edu.

Printed in the United States of America

Suggested citation: National Academies of Sciences, Engineering, and Medicine. 2016. *Art, Design and Science, Engineering and Medicine Frontier Collaborations: Ideation, Translation, and Realization: Seed Idea Group Summaries*. Washington, DC: The National Academies Press. doi: 10.17226/23528.

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The *Futures Initiative* is designed to enable scientists from different disciplines to focus on new questions, upon which they can base entirely new research, and to encourage and reward outstanding communication between scientists as well as between the scientific enterprise and the public. The Futures Initiative includes three main components:

Futures Conferences

NAKFI accomplishes its mission by harnessing the intellectual horsepower of the brightest minds of people from diverse backgrounds who attend an annual "think-tank" style conference to contemplate the real-world challenges of our day, having been prepared for deep conversations though

pre-conference tutorials. NAKFI conferences are intentionally crafted to allow multiple ways for attendees to interact. Some of the conference components are familiar, such as plenary sessions, but the expected gives way to the unconventional at a NAKFI conference. The format of *Futures* Conferences evolved from a traditional program of lectures and panel discussions to a meeting focused on providing a variety of venues for conversation. The foundation of this approach is the appointment of conference participants to seed idea groups charged with finding solutions to real-world problems. In addition to working in these concurrent groups—each of which reports on its work mid-way through the conference—participants have many opportunities for informal conversations and collaboration during "free" times and meals.

NAKFI has inspired its diverse network to "think big" at the frontiers of science, engineering, and medicine. And this is just the first step in its role as conversation shifter, idea incubator, career changer, and venture science funder.

Futures Grants

Futures grants are awarded to conference participants to enable further pursuit of new ideas and inspirations generated at the conference, conceptualized as "venture science," similar to start-up capital in the business world.

Futures grants serve as an incentive for attendees to collaborate after the conference and provide resources for startup research projects. Grants can also be awarded for meetings that explore a facet of *Futures* conferences in more depth or with a different audience. The grant application process is straightforward and reporting requirements are kept to a minimum. Principal investigators have already been vetted by the conference steering committee for attendance at the conference, and the grant selection committee looks for projects with the greatest potential to succeed. At the same time, it is willing to support high-risk propositions. NAKFI encourages grantees to learn as they go and to make changes to their plans as appropriate. Projects that experience unexpected delays or need more time can request a no-cost extension with a simple email explanation. Final reports cover a few key areas of interest to the program and encourage investigators to reflect on what worked, what did not work, and why.

NAKFI Communications

The Communication Awards are designed to recognize, promote, and encourage effective communication of science, engineering, medicine, and/or interdisciplinary work within and beyond the scientific community. Each year the *Futures Initiative* awards $20,000 prizes to those who have advanced the public's understanding and appreciation of science, engineering, and/or medicine. The awards are given in four categories: books, film/radio/television, magazine/newspaper, and online. The winners are honored during a ceremony in the fall in Washington, DC.

NAKFI cultivates science writers of the future by inviting graduate students from science writing programs across the country to attend the conference and develop Seed Idea Group team discussion summaries and a conference overview for publication in this book. Students are nominated by the department director or designee and selected by program staff. They prepare for the conference by reviewing the pre-conference tutorials and suggested reading, and selecting a Seed Idea Group in which they would like to participate. Students then work with NAKFI's science writing consultant to finalize their reports following the conferences.

Facilitating Interdisciplinary Research Study

During the first 18 months of the *Futures Initiative*, the Academies undertook a study on facilitating interdisciplinary research. The study examined the current scope of interdisciplinary efforts and provided recommendations as to how such research can be facilitated by funding organizations and academic institutions. *Facilitating Interdisciplinary Research* (2005) is available from the National Academies Press (www.nap.edu) in print and free PDF versions.

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Preface

At the National Academies Keck *Futures Initiative* Conference on Art, Design and Science, Engineering and Medicine Frontier Collaborations: Ideation, Translation, and Realization, participants were divided into Seed Idea Groups comprised of 6-8 attendees. The groups spent nearly 20 hours over 3 days exploring diverse challenges at the interface of science, engineering, and medicine. The composition of the teams was intentionally diverse, to encourage the generation of new approaches by combining a range of different types of contributions. The teams included creative practitioners from the fields of art, design, communications, science, engineering, and medicine, as well as representatives from private and public funding agencies, universities, businesses, journals, and the science media. Participants represented a wide range of experience—from postdoc to those well established in their careers—from a variety of disciplines that included art, design, science, engineering, medicine, physics, biology, economics, and behavioral science.

The groups needed to address the challenge of communicating and working together from a diversity of expertise and perspectives as they attempted to solve a complicated, interdisciplinary problem in a relatively short time. Each group decided on its own structure and approach to tackle the problem. Some groups decided to refine or redefine their problems based on their experience.

Each team presented two brief reports to all participants: (1) a 1-minute pitch, including a summary of idea; the first testable proposition(s); and remaining questions/stumbling blocks; and (2) a final presentation on Saturday, when each team:

- Provided a concise statement of the problem;
- Outlined a structure for its solution;
- Identified the most important gaps in art, communication, science, and technology and recommended research or activities needed to address the problem; and
- Indicated the benefits to society if the problem could be solved.

Each Seed Idea Group included a graduate student in a university science writing program. Based on the team interaction and the final briefings, the students wrote the following summaries. These summaries describe the group's process and the potential educational, cultural, social, and scientific impact of the group's proposal.

Each participant brings varying levels of knowledge to the topics included in this year's conference. To help create a common language for the meeting, participants were asked to engage in pre-conference learning and to participate in a pre-conference activity related to their Seed Idea team prior to the November conference. Attendees were encouraged to watch a variety of videos first and then think about the content specific to their Seed Idea team.

Contents

Conference Summary

Nadia Drake

Science and art were not always two separate entities. Historically, times of great scientific progress occurred during profound movements in art, the two disciplines working together to enrich and expand humanity's understanding of its place in this cosmos.

Only recently has a dividing line been drawn. Science, it often seems, is perceived as a rigorous pursuit of knowledge; art, on the other hand, as a less rigorous pursuit of expression. It's a superficial and false dichotomy, and misses some of the fundamental similarities between the two endeavors: At their best, both art and science are the ultimate embodiment of intuition, curiosity and creativity.

It's just that the rules for each are a little bit different.

"Great scientists are like great artists. They have a vision of the world," said Don Ingber of the Wyss Institute for Biologically Inspired Engineering at Harvard University, during the opening session of the 2015 National Academies Keck *Futures Initiative* conference. "They see something different and try to communicate it—we just have to do it so that other people can repeat it and other people can advance it."

Indeed, rather than orbiting along endlessly separated pathways, art and science often converge. Sometimes that convergence occurs in projects or experiments; sometimes it's in a person. Take, for example, Alexander Borodin, the 19th-century chemist and classical music composer. Or, to state the obvious, Leonardo DaVinci. There's also the entire "Dance Your Ph.D." contest, sponsored by the American Association for the Advance-

ment of Science, and origami-inspired folding spacecraft designs, among many other examples.

Or Ingber, the scientist whose game-changing insights into the behavior of cells were prompted by a sculpting class he took as an undergraduate in the mid-1970s.

"I went back to the cancer lab and they were treating cancer cells with a drug and it caused the [cells'] shape to change, and I said, 'Oh, the tensegrity must have changed!' And the postdoc looked at me and said, 'What's that?'" Ingber recalled.

In truth, transformation and innovation often happen most explosively in the space where art and science meet, where institutional walls are broken down, where it's acceptable to be uncomfortable with uncertainty. That's why this year's NAKFI conference created space for the intersection of these disciplines. Appropriately, this year's meeting was in some ways unlike those in previous years—it incorporated art installations set up throughout the Beckman Center—and, as with all experiments, some of the results were spectacular and others were somewhat less lustrous.

SCALING THE WALLS

One of the themes that emerged during the 3-day conference was the idea of toppling barriers and constructing nontraditional solutions.

Half of the conference participants were scientists and half were artists. As in previous years, participants were divided into small groups and asked to address such problems as using art to influence environmental monitoring, and music and dance to engage human collaboration in different ways.

Each challenge existed squarely within an aesthetic and design framework—considerations that are often missing from normal scientific inquiry but that often contribute to uniquely successful innovation. As attendees were reminded at the very start: "The answer to every 'How will we?' question is always the same: Innovation," said C. D. Mote, president of the National Academy of Engineering.

"How will we provide fresh water and food for the planet? Or cure cancer? Or found a colony on Mars?" he asked. "Innovation."

Different synergies emerged as the groups wrestled with the breadth of their assigned challenges. That's because testing interpersonal dynamics while attempting to whittle a massive question into something solvable is undeniably tricky.

"It's been fascinating to see the mix of people and how they work to-

gether," said the Wyss Institute's David Edwards, chair of the conference steering committee. "Of course it's led to new and sometimes frustrating conversations, given that artists and scientists all have different ways of expressing value, or understanding value."

Edwards spoke at the start of the conference about the difficulty of encountering institutional walls—or barriers that are not so much real as vestiges of the old guard. In those situations, he said, sometimes the only way to make progress is to push on the walls until they break.

"We often do it on the sly because nobody in our institute wants to know about it," Edwards said. "They want us to be innovative; they just don't want to know about the holes in the wall."

Developing a shared language, or a shared way of expressing value, is key to a good outcome within a team. But that's not the only thing that matters. The best synergies occur in groups where it's safe to grapple with ideas and flail while seeking an anchor, to be uncomfortable with ambiguity and uncertainty. That's when intuition and imagination take over. Several of the groups incorporated this kind of thinking.

"What you're seeing here is really bringing people back to the origins of their creative life," Edwards said. "You have such experienced people —their ability to dial back to kind of the innocent person that they were at one point, or to accept that they can be that innocent person again—let alone celebrate it—I don't know if it's limited, but there's an inertial thing going on there."

BEING COMFORTABLE WITH DISCOMFORT

Another recurring theme was confronting discomfort—of sitting with it, interrogating it and understanding it, rather than running away. It's a concept that, even on its own, can make people squirm. Yet there's much to be learned by plumbing the depths of discomfort.

Dancer and choreographer Liz Lerman challenged conference participants to do just that when she had the full group engage in what amounted to improvised dance among amateurs. Not only did she want participants to move in unfamiliar ways—and in close proximity to other people—she was asking them to leave the relative comfort of their minds for a short period of time and look to their bodies as instruments and sources of inspiration.

"Sometimes people are afraid to get into their bodies because they're afraid they're going to lose their minds," Lerman said at the start of the ex-

ercise. "But we really want to think about a partnership between our minds and our bodies. Our bodies have incredible things to tell us."

She started what was a simple walking exercise, having people move through space and introduce themselves to others around them. Then she asked them to interpret certain scenes or thoughts with their bodies. The next step was to teach those movements to a partner, who would then try and replicate the "dance."

The movements people came up with were tentative at first, but as the exercise went on, they became bigger, more animated, and more organic. "The body knows and records things you're not even aware of," remarked one of the participants. "Not being surrounded by talking heads is really liberating," said another. "The same gesture can mean so many things!" was another comment.

The twin ideas of turning to one's body and embracing discomfort found homes in some of the work the challenge groups presented.

FROM DREAM TO PERFORMANCE

And in the end, the teams presented their ideas not only with traditional slides but a bit of performance art. Instead of sending one group member to the stage, armed with a PowerPoint presentation and 10 minutes' worth of words, teams began to embody and demonstrate their concepts.

Some small, some large, these were all steps forward that had been conceived and realized within the shared spheres of art and science. And that's exactly what the NAKFI conference was aiming for.

"We're not asking you to tell us how to solve the world's problems because we don't really know," Edwards said. "Nobody here is really smart enough to know what the world will be like 20 years from now," Edwards said, presciently, at the beginning of the conference. "We're about dreaming here. You can't be a country of pioneers and not have been founded on this notion of the dream."

Machines and the Human Biome at the Frontier of Medicine Science

CHALLENGE

The human biome is a contemporary frontier of medical science. Might machines be imagined that enter the gut non-invasively and monitor, diagnose, or treat human health in original breakthrough ways?

SUMMARY

Teresa L. Johnson, NAKFI Science Writing Scholar
Johns Hopkins University

The group thinking about Machines and the Human Biome at the Frontier of Medicine Science took on the challenge of conceptualizing machines capable of non-invasively entering the gut to monitor, diagnose, or treat human health and disease.

The gut plays an integral role in human health. Elements of the gut interface with the body's internal and external environments, and respond to a diverse array of challenges ranging from the food we eat to the microbes that live in our bodies. The gut's multilayered structure, self-regenerating capacity, and diverse ecology provide an intricate and sophisticated system for policing the human body's inner borders. A key element in this system is the vast population of microbes that inhabit specialized niches within the gut. Collectively referred to as the microbiota, these microbes outnumber their human host's cells by a factor of 10.

Almost no two individuals share the same microbiota, but similarities exist across family members, generations, and cultural groups. The microbiota and the genes it harbors constitute the human microbiome.

Humans coexist with their microbial partners in a symbiotic relationship in which host and microbes benefit one another. The human host provides a nutrient-rich, oxygen-free environment conducive to microbial growth, and in turn the microbes participate in nutrient synthesis and absorption, modulate cell signaling, regulate neuroendocrine systems, and mediate host defense mechanisms. Comparable to large populations of humans, these microbes act in communities and display community dynamics to modulate human health in ways not fully recognized or understood.

Current research has focused on the microbial diversity in the gut, characterized by its richness (the total number of species) and evenness (the differences in the abundance of the various species). Early measurements of the microbiota's diversity arose from laboratory culture-based studies of anaerobic microbes. More recent culture-independent methods rely on highly conserved microbe-specific molecular markers and environmental sequencing, providing insight into the functional potential of this highly sophisticated biological system.

Technologies for modeling interactions between disparate biological systems, such as humans and their microbial symbionts, do not exist currently. As such, a key dimension of health assessment is absent. Research suggests that an integrated model would provide insight into a variety of health concerns, including autism spectrum disorder, cognitive function, fertility, immune function, inflammation, mood, neurodegenerative disease, obesity, psychiatric disorders, and others.

The group hypothesized that the diverse, dynamic microbial community in the human gut produces measurable sound, and this sound can be interpreted as a reflection of either health or disease. Physicians and nurses have long relied on sound as a means to monitor health and diagnose disease. For example, the sound produced during percussion, or gentle tapping, of the abdomen, back, or chest wall aids a practitioner in determining the presence of anomalies such as fluid in the lungs, or a mass in the gut. Auscultation with a stethoscope of the neck or chest may identify cardiovascular or respiratory dysfunction such as dysrhythmias or constrictions, respectively. Similarly, listening to the abdomen provides information about blood flow to the gut, peristaltic movement, and bowel disease. New insights into molecular cell biology suggest that some elements of cell signaling can be described by sound.

The group proposed the development of a means to detect and integrate the myriad ways the human body and the microbiota communicate and deliver information—an InnerNet. Analogous to the Internet, the InnerNet will tap into the communication networks of the billions of microbes that reside in the gut and their vast collection of "voices."

The adage, "Listen to your body," will become a reality, providing humans the opportunity to communicate with their inner symbionts and make informed decisions about their health. An advantage to such monitoring is that it will give a voice to individuals who are unable to communicate subjective information regarding their gut function, especially the very young or the very old, and will tap into the "quantified self" movement in healthcare, thus empowering users to modulate their health through utilization of data.

Implementation of the InnerNet requires advances in computation and the accompanying algorithms that make sense of data; new detection tools; and new user interfaces for healthcare providers and individuals to intuitively manage this information. As a first step, the group suggested a multidisciplinary, three-tiered approach that emphasizes knowledge acquisition, crowdfunding, and business development.

Knowledge acquisition would occur in a workshop setting in which a small team of experts can enlighten, imagine, and collaborate. The team identified several areas of expertise required:

- complex systems modeling
- sonification/sonic analysis
- sensor design
- crowdfunding/documentary
- wearable technologies
- health sciences
- technology transfer/intellectual property
- others

The group imagined several possible implementation schemes for their InnerNet, including utilization of external intimate contact sensors in clothing or temporary tattoos; internal devices such as BioSilk, a novel, patentable sensor/microphone array that can interface with an individual's smart phone or smart home, and provide real-time analysis of anomalies within the gut; and others. Sensor output will emphasize causal triggers that stand out from ambient background noise. Some devices will be pas-

sive (monitoring/diagnostic), while others will be active (therapeutic); both will address acute and chronic health needs. These varied approaches will take into consideration the rapidly changing dynamic of the human gut and health.

The team anticipates rapid dissemination of the newly developed technology to developing nations, ensuring widespread access to the new medical devices, especially in low-resource settings, and providing a layer of healthcare not currently available.

Designing a Healthcare System That Promotes Learning and Caring

CHALLENGE

There is a grand opportunity to shape massive healthcare systems that support patients seeking wellness, clinicians delivering care, and providers eager to reduce costs, while increasing the quality of care. Big Data analytic tools could provide insights at every level, which could be shared with relevant stakeholders, but producing meaningful changes in such massive systems remains a challenge. Bottom-up strategies could propel patient and clinician participation, while top-down governance is needed to set policies, cope with malicious actors, and guide continuous improvement. How can a set of guiding principles, vision statements, and governance structures shape the next 30-50 years for the evolutionary development of the learning health system (LHS)? What creative embryonic ideas can grow into a safe and effective LHS that is plastic enough to accommodate change, yet sturdy enough to be reliable and predictable? What models can we draw on from biology, arts, urban planning, or genomic assembly? What lessons from socio-technical systems design can be applied to get the best combination of bottom-up initiatives and top-down leadership? What blend of quantitative Big Data and qualitative ethnographies can provide guidance for managers, so they can adjust the game theoretic mechanisms that govern motivation for patients, providers, and insurers? In short, how can we design a caring healthcare system?

SUMMARY

Sydney Devine, NAKFI Science Writing Scholar
University of Georgia

The relationship between doctors and patients in the United States has been changing for the past decade or more, as patients ask for more say in their care, and physicians, hospitals, and health insurers encourage them to take charge of their own well-being. Thousands of smart phone apps and online programs exist so you can count your steps, track your heart rate, diet, and sleep, or call a nurse 24 hours a day. Each is intended to generally encourage well-being. The group on healthcare proposed the development of an app that it believes will be even better than existing apps such as MyFitnessPal, which help individuals track their daily calories, or the ever-so-popular FitBit, which counts your steps and encourages you to increase your daily exercise. No two people are identical, however, and each person's health goal is different from the next. The group has developed an app that will combine these features and more, by giving app "players" the chance to compete against others in a wellness game—the final prize being the achievement of what is currently known about a healthier life.

To accomplish this, the team focuses what it calls "wellness motivation." How can the team build something that will make people motivated not only about their health, but also their wellness as a whole? An individual's wellness can be sliced into seven different dimensions: physical, emotional, intellectual, spiritual, occupational, social, and environmental. Team members refer to these seven parts as the "wheel of wellness," and they presented the seven types in a spinning color wheel that encompasses their idea of well-being for the whole person. "Each of these different dimensions plays a key role in an individual's life and how an individual feels every day. Wellness depends on how you relate to others, how you interact each day, how you feel when you wake up in the morning. It's how you engage with life."

Although people want to be healthy, that's often easier said than done, as daily life gets in the way of maintaining good diets and exercise routines. New technology has only added to everyday distractions that have existed before. Understanding the strong influence that technology has on our lives today, the group decided to design a plan that is supported by technology.

The group asked whether it could improve an app that reminds people to stop and meditate for 1 minute each night, or whether it could make a

better app to allow real or online friends to "challenge" you to get 1 extra hour of sleep. Could the team develop a better way to remind people to work out and accompany that reminder with helpful tips on what to do? Also, in an ideal world that same app would help people eat right, while offering guidelines and recipes about food, making it simple. And what if the health-conscious app user, in the end, could track these changes and see where they've improved? The "Wellness Game" the group imagines builds on the idea that games can be addictive. Games hook people into playing. There will be winning, losing, challenges, and even teams.

Thinking about the different types of games that are popular today, the team decided it was a good idea to choose something as a model for their particular wellness game. The issue with games, however, is oftentimes the players involved become frustrated or bored with the content and give up—therefore, a recurring element of surprise is an important element.

The game to model the plan after needed to be something that has been wildly popular and successful. Finally, a team member came forward explaining that there are more than 57 million users on the popular game Fantasy Football, a game that drops the player into a virtual world of sports, where they serve as the coach and the littlest change could blow the game. It involves the player selecting his or her own team from the National Football League roster. After drafting your choice of players, you compete against other football team owners. The players then compete using their football skills and knowledge to win the championship. The competition keeps the game alive.

Learning how to play is simple and millions are involved, so the team decided "Why not?" Why not make a Fantasy Wellness version, mirroring it after the ever-so-popular game. The team then mapped out the basics of their new game. Players would begin by creating a profile that would include data from some sort of screening process, through which individuals would insert health information about themselves. Perhaps they'd also set goals—what parts of the seven dimensions of wellness from the colorful wheel mean the most to them and where do they want to see themselves improving.

Next is drafting your team. Players of the game could pair up with friends, family, co-workers, and even strangers to play on their team. Each team player would contribute to the team by reaching wellness goals—each person will have her own set of goals based on needs and lifestyles. Goals could be anywhere from Player A wanting to lose 2 pounds per week to Player B wanting to complete a 5K by the end of the month.

Teams will compete against each other. Players are motivated by the competition and motivated by their other team members. The ultimate goal is to remain engaged and to improve wellness overall.

After some of the more important details were decided, the team finally chose a name for their game: Human Race. Human Race will make wellness an everyday part of life. It will make health interesting for those involved and encourage players to complete wellness goals—giving them a healthier lifestyle and shaping the current healthcare system into a better, holistic one. Technology constantly forces its users to think about the next awesome, innovative device to come.

The group ended its discussion and presentation of the new game with "imagine." They asked the audience to imagine the possibilities of their game. Imagine what the game would do to the healthcare system—saving costs, improving health, motivating consumers. Imagine who would use the game, and what this game would save. Imagine future wellness games to come: Calorie Crush, with similar rules as Candy Crush, or Family Fit Feud, mirrored after the well-known Family Feud television show, or Mindfulness Craft, to mock the addictive video game Minecraft. Just imagine the wheel of wellness shaping the world of wellness into a better, more effective system.

Imagining New Ways to Use Music in Education and Health

CHALLENGE

To hear, to listen, to empathize: Now that technologies such as neuroimaging have illuminated the depth of music's impact on the brain, what will be the next breakthrough, from translational to therapeutic? How can new machines and old (traditional musical instruments) work together to enhance music's role in education and health?

SUMMARY

Amy McDermott, NAKFI Science Writing Scholar
University of California, Santa Cruz

The "music" imagined new ways people could gain access to music that will improve cooperation, problem solving, and well-being. The group envisioned a simple device that will let people make music together, whether they are musically trained or not.

When humans sing, dance, clap, and make music together, they act in synchrony. Studies have shown that this kind of collective behavior activates neural networks associated with social and emotional processing and cognition, correlated with positive behaviors and group cohesion. In young children, for example, rhythmic playing and singing are associated with a significant increase in spontaneous helping and cooperative problem solving.

The group set out to design a device to tap into the cooperative power of synchronous behavior. The team focused on the value of music to groups like work colleagues, and students. At the same time, it did not lose sight of the benefits of music to individuals.

Keeping a Rhythm: Metronomes Help Us Synchronize

To design a device that helps groups synchronize, the team used the metronome as a starting point. The classic instrument keeps time at a constant rate. Traditional metronomes are frustrating in their consistency: for someone who lacks a strong sense of rhythm, it's hard to keep in sync. But some metronomes can be programmed to make small adaptations to account for human inconsistency. The small adaptations shepherd the musician who lacks rhythm toward synchrony.

The team focused on adaptive metronomes because they have been used in previous studies of synchrony and cooperatively, both for functional magnetic resonance imaging of the brain and in educational therapies. Interacting with the metronome as an adaptive "virtual partner" has been shown to improve attention and motor control and to reduce aggression in children with attention deficit disorder or attention deficit hyperactivity disorder, for example.

The team wants to advance this technology by developing a platform that can adapt to users with different skills. In previous studies, adaptive metronomes have been used with one user at a time. Scaling up to group interaction could provide broader scientific insight on the metronome's potential beneficial effects.

Implementation: How Would It Work?

There are several imagined prototypes. A sensor, interpretation module, corrective filter, and microphone were the basic elements required. The sensor and microphone would "hear" users and respond, while the interpretation module and filter would analyze and correct variation between participants. The corrective filter would have multiple settings, so that users could decide how much to let the adaptive metronome guide them.

One team member suggested the technology could be a glowing block, which would send and receive musical signals, in addition to adapting to the individual. Participants would each have their own block, allowing them to interact individually, or to engage socially.

Alternatively, the technology could be more like a group game, with a single device serving multiple users at once. In this case the metronome would need to discern between individuals by tracking their movement or sound.

A simple alpha version might be a flat surface, programmed to respond to tapping, like a smart drum. This surface would communicate with assessment tools to "read" the tappers' rhythms and adapt to minimize variation over time.

A Question of Philosophy

The team defined its goals and zeroed in on the adaptive metronome as an appropriate tool particularly because it can be useful to a large number of people who might benefit from technologically-mediated music-making as an explicit tool for social cohesion, not a replacement for music training. Rudimentary, musical engagement would allow anyone to participate. It would lower barriers to entry, so people without musical training could access the psychological benefits of creative collaboration.

Conclusion

The music group agreed that an adaptive metronome, scalable for group participation, is the next step in music therapy and the study of rhythmic synchronization. The new tool would be useful in a variety of contexts, from the boardroom to community meetings, to the classroom, to the counselor's office—anywhere increased group cooperation is beneficial.

Restoring Physical Intuition

CHALLENGE

Increasingly, individuals are interacting with the world through the virtual interface of computers. Children play with iPads rather than blocks or erector sets. Physical intuition plays a role in invention of physical objects, architecture, and engineering. None of us is totally disconnected from the physical world, which is potentially a dangerous place requiring intuition to navigate safely. How can physical interactive displays be used to allow people to test their own physical intuition that develops through interaction with the real world and emerge with at least an awareness of its importance and their level of proficiency?

SUMMARY

Katherine Ellen Foley, NAKFI Science Writing Scholar
New York University, Science, Health, and Environmental Writing Program

The team worked on ways to define and improve physical intuition in an increasingly technological world and concluded that the core problem is that, as we become more dependent on technology, we lose some of the sense of connection with our physical bodies. For example, our cell phone screens may distract us at the office, and, more dangerously, they may also command our attention while we walk through city streets. They may put us at risk for tripping or having an accident, but also take opportunities

away from us to make social connections with others. This potential disconnect can ultimately affect our work and well-being.

"Learning intuition in one area helps you learn intuition in other areas," said one member of the group. The group discussed how this idea—known as knowledge transfer—could apply to both the digital and the physical world. For example, when a user understands how to use one computer program, he can likely apply his skills to navigate others manufactured by the same company. Conversely, if a woman has a background in rock climbing, she will likely be able to use the same physical intuition to cross an icy pathway without falling.

The group recognized that knowledge transfer through different activities could help people solve seemingly impossible challenges by inspiring them to think of creative solutions. Often, when we're stuck on a problem, stepping away from it and engaging in an unrelated activity gives our mind a chance to wander. When we later come back to the task at hand, we'll often find that subconsciously, we've thought of a totally novel approach to solve it—indirectly inspired by the irrelevant task. The group decided that they wanted to provide people with a means of gaining additional knowledge transfer through "tools of unknown purpose."

Tools are only tools in the context in which they are used. "Tools of unknown purpose," therefore, are similar to toys: They are objects with no specific use, and can therefore be applied to whatever task we choose. For example, in a construction setting, a hammer can be used to nail boards together. In an artistic setting, though, it could be used to uniquely spread paint across canvas. The group felt that playing with these ambiguous tools could help reboot physical intuition and social experiences in an increasingly technological world by forcing us to think creatively outside of our daily routine.

"Tools of Unknown Purpose: A Traveling Exhibition," would be a mobile demonstration. It would start out by working with teenagers—who straddle the playfulness of childhood and the experience of adulthood—and ultimately reach diverse groups, including children, people who are temporarily or permanently physically disabled, and adults. The team envisioned that it would be a "containerized toolshed . . . of ambiguous tooling, lost ritual, and specialist profession," according to a member of the seed group.

They envisioned that the exhibit would be held in a shipping container, similar to a train car, filled with items ranging from dental tools, construction devices, and unidentifiable objects for participants to touch, feel, and use to alter materials—all without descriptions. It will appear in locations

such as college campuses, farmers' markets, shopping malls, and community centers for about 1 month at a time. By providing tools that are "mysterious, intriguing, and obviously related to the body," according to a member of the group, the exhibit will encourage participants to play with physical materials, and take time to disengage from technology as much as possible.

Participants will have the opportunity to use these tools to play with, mold, create, and destroy structures made from plywood, plastic, and materials unique to the local environment, such as different types of timber, debris from storms, or even scraps of materials community construction projects. This approach is more environmentally friendly and ensures that each location provides a unique experience.

The tools featured in the exhibit will be a mix of relics from the past and future: Some of the tools will be objects like ancient dental or culinary tools. Others will have a futuristic design, like "complex tooling for navigating difficult virtual data-scapes," as one team member said. There are no wrong ways to interact with any of these items; the team emphasized that participants should know that it's impossible to fail during their time in the exhibition. The purpose of these tools is to encourage participants to play in ways that may not solve an immediate important need. In the group's final presentation, one member suggested that some of these tools could be used to create remixed versions of popular songs, including Drake's "Hotline Bling."

The group recognized that it would be important to collect data about how participants use these tools. They envisioned that each of the tools will be equipped with software to record the ways in which they are moved and used. By studying the different ways people use these items, the exhibition will help develop a metric for measuring physical intuition. Ultimately, these data could then inform the ways we could ultimately improve physical intuition. These same metrics could demonstrate the ways in which the program is successful and how it could be improved in the future.

The group proposed additional ways for teenagers specifically to engage in the exhibit. First, it will only employ other teenagers to guide participants, in order to make it more accessible. They concluded that teenagers would most likely respond with less inhibition and more open minds with these tools if they felt they could relate to a peer. In addition, some members of the group wanted to engage teenagers' own digital presence. Rather than trying to force participants to give up their phones, they decided that they could take pictures and videos of users while they meander through the exhibit. At the end of the show, participants could choose which of the

images or videos they would like uploaded to their personal social media accounts, such as Facebook and Instagram.

Only at the end of the show would users learn the original intent of each of these tools. Ideally, they will be both surprised by how their own intuition differed from the original design, and filled with wonder as they connect with these tools in the same way they were intended years ago.

By recognizing their own creativity, participants will retain a lasting reinforcement of their internal physical intuition. As each of the group members discovered through personal experiences, having creative physical intuition can solve challenges across a variety of disciplines. Awareness of physical intuition—and a newly sparked curiosity about its value—will create a network of 21st-century problem solvers that will approach technological challenges from unique stances.

Our dependency on technology to solve problems will not change, but we can remember to emphasize the importance of physical wonderment as we advance both sciences and art.

Creating Sustainable Futures in a World Increasingly Dependent on Technology

CHALLENGE

In today's interconnected world—which is undergoing deep and rapid transformation—we must re-vision education for a new global context of learning; one that can account for the promising knowledge horizons that science, engineering, and medicine already signal, and for the humanistic grounding and ingenuity that art and design afford us. Might we be able to chart a course forward through new educational models, products or systems that can challenge the purpose of learning and redefine what competencies and skills might matter the most in order to lead us to a more sustainable and equitable future?

SUMMARY

Lauren Schumacker, NAKFI Science Writing Scholar
University of Georgia

The team was asked to tackle the issue of creating sustainable and equitable futures in a world increasingly dominated by technology. The team decided that the fundamental issue pertaining to this larger problem is a pervasive lack of empathy within the global community and an overwhelming expansion of feelings of indifference. Therefore, they propose the following project: Empathy in an Expanded Field: Stemming the Rising Tide of Indifference.

This project will function within the framework of an "appreciative inquiry" that asks people to cite pressing problems they are facing themselves, rather than allowing academic or other activist experts from outside of the community to tell them what their problems are. The team established its own approach for conducting such a community inquiry. The first is to find a way to bring all the stakeholders to the table. In order for appreciative inquiry to work, community members who care deeply about what is going on around them have to be invested and work collaboratively. Then, facilitators will be selected and trained so that the community is able to identify problems as well as determine which are most pressing and, therefore, should be prioritized. The facilitators will also work to help break down the problems and reach realistic and feasible solutions.

The team decided that the pilot program should operate in Merced, California, an area that has very poor air quality and high levels of pollution. Also, the community in Merced has already raised the issue of air pollution and stated that it is one, if not the most, important problem they are facing and one that they want to alleviate.

One potential manifestation of this program is the creation of avatars designed by those who have respiratory and other diseases that are made worse by poor air quality. These avatars would be available to neighbors, the community, and the world through a cell phone application that would allow people to see who is truly affected by their decision to drive to the store on a day when doing so would further debilitate someone suffering from a condition such as asthma. Developers would create the application, but then users would have to download it and log in to track how their neighbors were doing on a given day. People could create their own avatars. In addition, an avatar could be created for an entire community of avatars for specific conditions, using aggregated data from local doctors' offices or hospitals. This would be similar to current practice of weather forecasters or public health officials who notify people when air quality is poor. Community-level avatars would allow individuals who don't feel comfortable being tracked/monitored to still potentially benefit from the technology and the project, while keeping their privacy intact. The whole goal of this project is to enable app users see how their behavior directly affects real people living in their community, thereby generating greater empathy for what their neighbors are going through. Perhaps some people would opt to keep their car at home on a day with poor air quality and walk or bike to the store, rather than running out for one small thing, for example.

Ultimately, the team hopes that more knowledge will lead to more

understanding and more empathy for what those affected by a given problem are struggling with and then result in actionable and real behavioral change. This project really has two end results: helping people become more empathetic toward their neighbors and community as well as solving the problem the entire community banded together to resolve.

Developing Programs to Engage and Empower Communities to Address Threats to Ecosystems

CHALLENGE

The threats to our ecosystems today are multiple—pollution, biodiversity reduction, rising sea levels, and ocean acidification. The consequences for the livelihoods, health, and futures of people living in those ecosystems, as well as for the health and lives of other animals, are serious. Develop a program—adventures, food experiences, citizen/public science activities, or other knowledge creation and sharing processes—that can engage a specific community in understanding their changing local ecosystems, and the factors involved, and empower them as stakeholders and stewards of these ecosystems.

SUMMARY

Lydia Chain, NAKFI Science Writing Scholar
New York University, Science, Health, and Environmental Reporting Program

This group was interested in developing programs to engage and empower communities to address threats to ecosystems.

Imagine standing on a Louisiana beach on a breezy summer day. In the distance, you spot it: The mythological creature of the Gulf greets you and your community with a dazzling display of colors, flashing fins, and triumphant water spouts. Your community cheers! The water along your coast is pure.

The team decided to tackle issues involving water. Our oceans and coastal ecosystems are under threats that are numerous and difficult to tackle. Lint and micro-plastics fill the seas, agricultural runoffs create dead zones bereft of oxygen, hormones and pharmacological chemicals leak from our wastewater and disrupt animal biochemistry, overfishing strips the trophic chain, and petrochemical manufacturing waste pollutes the water.

The Gulf of Mexico has additional problems because of the Deepwater Horizon oil spill in 2010, the fact that the sea level rise is destroying coastal communities, and from an increase in the frequency of hurricanes.

The lack of community coordination and awareness of environmental conditions is striking in the states and nations surrounding the Gulf of Mexico. The team wanted each of the Gulf States, as well as the nations that border the Gulf, to come together to study, understand, celebrate, and improve their waters. The Gulf is a place where an intervention to help people be stewards of their ecosystem may be of the most use, but the group wants to design a project that can be easily adapted to different coastal environments.

The group envisions an art project that will raise awareness, create media attention, and stir community engagement, while providing citizen scientists with data about their environment. The group wants to build MARU, a Mobile Aquatic Research Unit, otherwise known as a robotic fish that will swim around the entire Gulf of Mexico in a summer. MARU will be outfitted with sensors to measure water temperature, current speed, water purity, trace chemicals, plastic levels, oxygen levels, and more in the aim of providing lots of information about the quality of the water.

MARU will be programmed to communicate with the communities through its behavior and physical appearance. There will be lights that change color depending on what's in the water. MARU's swimming patterns will tell a story, as will whether it spouts water or smoke. Perhaps sickly yellow smoke will spew from the robot's blowhole if there are high levels of contamination in the water. If the water is clean, there may be a display of sparkling lights and flashing fins to reward and celebrate with the community.

MARU will provide real-time information about water quality in the Gulf, streaming data to a website that people can analyze. Its eyes will hold a camera feed, providing a live video stream. People will be able to see what the robot fish is experiencing in any moment: schools of fish, whales, birds, and even themselves waving to it from the shoreline. There will also be an

audio feed, perhaps broadcasting on AM radio, which is, according to one member of the group, still one of the most frequently used forms of media.

The team hopes that a mythology will build around this creature. They intend to design it to incorporate mythological elements as well as features from extant and extinct Gulf animals. Because the project is intended to involve communities, they will also include the public in the design process and work to include elements that communities find important. Even the name might be open to community input. "The mythology of the creature is similar to the mystery in the 'here there be creatures' in ancient maps" said one group member. "It's still sort of a mystery what goes on in the Gulf waters." The team hopes to shine a light onto those mysteries and enable communities to learn about water quality for themselves instead of relying on agencies they may not trust.

This is not just a data generation project or a mobile art installation, however. The team wants to accompany the project with a template for event planning and educational toolkits. As the robotic fish travels to a given community, that community would have access to materials to plan a festival, a workshop, a sighting—whatever the community decides would be best for it. Organizers will reach out to community groups, youth groups, church groups, and universities to create events. Workshops will provide scientific context for the artistic display and anchor the information in the current problems and observable data about the environmental condition of the shoreline. One example is a workshop to collect shrimp and score the water quality based on mutation rate in the shrimp. These sorts of projects will especially educate children about what is going on in their world while providing an engaging and exciting event.

The team also hopes to guide the community toward action. They do not want to provide a data dump devoid of context that might cause rifts within communities, if people come to different conclusions about the data. It's important to help people understand the real-world significance of a certain pollution level, and provide resources to taking the next step of action. This must be carefully balanced with not forcing a certain viewpoint upon the community and letting them make their own decisions. A town can't feel ownership over its environment if they do not choose their own course of actions based on good information.

Robotic drones that skim the water's surface already exist. One such robot is the Wave Glider by Liquid Robotics in California. It is an autonomous drone, about 10 feet long, propelled by solar energy and wave action. So far, Wave Gliders have logged more than half a million miles in

the water and weathered 97 hurricanes, making them proven and durable options. The group hopes to build the fish around these sorts of preexisting technological frameworks, which will minimize the cost of development and the risk of catastrophic failure. They will add functionality and aesthetic appearance, but will not need to reinvent the technology.

One group member has deep ties in the Louisiana community of Grand Isle, a small town with fewer than 2,000 permanent residents, although they are joined by 18,000 tourists during the summer. It's a historically disadvantaged community that is already home to several ecofairs, including the Grand Isle Migratory Bird Festival. The team could build on current programs and test several educational programs and festival events. They may use a boat to accompany the fish, giving people a closer view at MARU and as a venue for activities.

This initiative will eventually create a Gulf-wide community, binding together disadvantaged and currently disengaged coastal towns. MARU will create informed conversations among community members about their ecosystem, and give them the tools to be engaged and passionate stewards of the Gulf.

Creating Open Data Culture

CHALLENGE

Open data means providing unrestricted data to everyone. There is a lot of data within the public sector and within science that are not as useful to benefit society as they could be if they were available to anyone at all. As one example, if we wish to understand the elements of the integrated system that is the Earth's atmosphere, oceans, and biosphere, the way those elements interact and how they have changed with time, it is necessary to be able to collect and analyze environmental data from all parts of the world and from many sources. In the public sector in recent years, many state and local governments have put effort into open data projects that would inspire developers to create apps and find ways to use public data to bring value to their communities. (It should be noted that the open data movement is not about getting data that people value as private and sharing them.) How can an existing open data set be used to create a project that highlights the idea of open data culture and demonstrates its benefits to society?

SUMMARY

Jennifer Hackett, NAKFI Science Writing Scholar
New York University

The open data group decided to address its challenge by proposing an app that could be used to prevent miscommunications across cultures. The

app would provide alerts when a potential miscommunication might occur, such as using a gesture that has different meanings across cultures. The challenge of using a huge data set for the public good was at the core of the team's thinking about important issues in large open data sets.

Conception of the app was made possible by the resources to which the team members already had access. Two members of the team have access to either a powerful, massive data set (data from assessments that came from massive open online courses, or MOOCs, which the team member develops) or a strong analytical tool (an algorithm to analyze spoken or written language for a variety of factors, including vocabulary and inflection). It was quickly decided that any proposal the team created needed to take advantage of these databases.

The team agreed that the best way to combine the available data set and analytical tool would be by studying the efficacy of language in teaching and outreach. By focusing on extremely successful professors who had consistent positive evaluations from students that were supported by quantitative data (such as student enthusiasm, retention rates, and success), the project would analyze their communication styles to determine what made them so successful. The open data set would come from the MOOC assessments paired with the recorded lectures, which are archived and digitized by definition as they are online coursework.

Initially, the intent behind this project was to show that when information is openly available it can be analyzed in ways that are qualitatively valuable and beneficial to society. Prior to the conceptualization of the Prism app, this proposal would have been for a study with no greater end goal outside of providing both qualitative and quantitative data to teachers about the traits of highly successful online educators.

Around this point the term "precision communication" was introduced. While this was adopted as a rallying term for what the team envisioned, it also raised some concerns due to its similarity to the idea behind targeted ads. The goals of the initial project—targeting language to the audience so that a message is communicated most effectively to the people most likely to be interested in it—were nearly identical to the goals of targeted ads. As the underlying goal was still to help the public in some meaningful way, the team decided to focus on finding a way to differentiate their plan from targeted advertising.

The team wanted to use communication analysis and information from the MOOCs. Establishing the most useful application of this analysis took

some discussion. An early idea was to study effective teachers and use that information to train retired professionals and older teachers to be more effective communicators in the classroom. This would not only benefit students by providing them better teachers, but would instill a sense of purpose in the retirees who became teachers or assisted in distance learning. This same communications training could be given to doctors and medical professionals, who would then be able to better communicate with their own patients. A way to build a stronger, multiuniversity data set was also proposed. The only way to access this data-driven retraining technology would be by making your data open access so they can be studied.

After a consultation, the team chose to add a larger end goal that the initial study would build toward. International research partnerships are standard, but miscommunication across cultures is inevitable, especially because there are so many international and cross-cultural interactions taking place at any given time. This end goal would be an app called Prism, which stands for Prevention of Intercultural Sensitivity Malfunctions, which would help prevent miscommunications across cultures.

The proposed app works by seeking out contentious or easily misunderstood phrases. The initial study of students and teachers participating in MOOCs would help distinguish words, phrases, and gestures that the app should search for, as well as alternatives for them that would be less susceptible to misunderstanding. As one team member said, the goal would be "to speed up communication via data." The app would be a natural next step in improving the efficiency and ease of communication. It would take both the speaker's culture and the audience's cultures into account to ensure effective communication.

This particular Seed Team worked together effectively from the start, with no major arguments and plenty of positive, encouraging discourse. Two members of the team provided the bulk of the driving power in terms of what tools the team had and what sort of analysis the team could do, while three members served as analysts who helped refine the idea to be helpful across multiple venues (healthcare, private business, and cross-cultural international research). After the final pitch, there was strong enthusiasm shown to continue working on and refining the idea for a formal proposal, a goal that all members of the team had in mind throughout the entirety of the conference.

Creating a Learning Educational System to Identify Benefits of STEM to STEAM

CHALLENGE

There has been considerable recent discussion of the importance of improving our STEM (science, technology, engineering, and mathematics) educational system at every stage in society: formal primary, secondary, and higher education; life-long and evergreen learning; and education of the general public. Exploiting the intuitive reach of art can be essential to conveying more effectively the critical messages of science, technology, AND medicine to our citizens; to enabling more informed choices about our future; and to building an innovative workforce. Furthermore, evidence demonstrating the effectiveness of this connection will be required to secure the resources and support necessary for required changes along the continuum of education. Can a "learning educational system" be developed to identify what current forms of art and design—visual, musical, multimedia interactive displays, both real and virtual—are most effective, and to identify possible new forms?

SUMMARY

Laurel Hamers, NAKFI Science Writing Scholar
University of California, Santa Cruz

The STEM to STEAM (science, technology, engineering, art, and mathematics) group was asked to create a "learning educational system" to assess the benefits of integrating the arts into science, technology, engineering, and math education. Proponents of STEM to STEAM, as the movement is colloquially known, claim that incorporating principles of art and design into science education will make students more creative and better innovators.

STEAM education is already being implemented piecemeal across the country. However, in a test-driven educational system that increasingly devalues the arts, convincing cash-strapped school districts and time-crunched teachers to prioritize STEAM is a hard sell. Even more challenging is effecting change at the policy level. A major barrier to system-wide implementation is the lack of clear understanding of the long-term benefits of including the arts in science. This is difficult, if not impossible, to assess via standardized testing. As such, there is no coordinated plan to implement STEAM on a larger scale.

Moving Beyond STEAM

The group argued that bringing arts into STEM is too often one-sided: art is used as a tool to improve science education but isn't valued on its own merits. Instead, the group envisioned an educational system that valued collaboration and integration across all disciplines. They wanted to see integration not just among scientists and artists, but also among engineers, historians, psychologists—an entire spectrum of specialists. And they wanted that collaboration to foster equal footing among the disciplines instead of inserting one into another.

Team members acknowledged that specialization can be important—one would expect a brain surgeon to have a solid grasp of the anatomy of the brain, for instance. But generally, the team felt that lack of cross-talk among disciplines hindered the ability to solve interdisciplinary global problems—issues like climate change and food shortages. By thinking about problems within the narrow focus of one field, researchers might miss important interpretations or context.

Such specialization starts young: team members noted that even children feel pressured to be either an "art person" or a "science person." Students who want to be both are told they must choose—or that one must remain a hobby, not a career. The team decided that emphasizing interdisciplinary education in K-12 schools could help reduce this divide by encouraging students to think about problems across disciplines.

The Undisciplined Classroom

The team focused on teachers, noting that the current educational model encourages (and sometimes forces) teachers to stick to scripted lesson plans that devalue teacher creativity and advocate a one-size-fits-all approach to teaching. They created a model for what it termed the "Undisciplined Classroom"—a project to encourage and inspire educators to teach (and learn) beyond disciplines.

As a pilot experiment, the group proposed a 1-week immersion that would take place in a brick-and-mortar facility somewhere in the United States. During the retreat, teachers recruited from the surrounding community would be put into cross-discipline groups to think about a "big question"—something that could be explored from many different angles and at many different levels of education. One such proposed question was "Who am I?" Such a question could be explored on a scientific level, in terms of anatomy, physiology, and neuroscience. It could be tackled philosophically by discussing the meaning of the self. Or it could be investigated historically, by tracing family roots. The goal was to present a question that could not be properly answered within the constraints of one discipline, to challenge teachers to cross disciplinary boundaries. Other suggested questions included "What is time?" and "Why do we dream?"

Over the course of 1 week, teachers would discuss these questions and their differing approaches to teaching them through a mixture of structured and unstructured activities. Teachers would also receive feedback from researchers in different fields. Then, they would collaborate to design ways to implement such interdisciplinary measures in their own classrooms in cost- and time-effective ways. Attendees would be compensated for their time and provided with accommodations like childcare in order to make the experience feasible regardless of socioeconomic status.

Throughout the year, teachers would periodically be invited back to the Undisciplined Classroom for weekend follow-up support sessions. There, they'd be able to discuss what worked and what didn't in their classrooms,

and provide feedback and support to their colleagues working toward the same goal.

The team did not fully agree on what the Undisciplined Classroom pilot project would look like from a physical perspective. Some imagined a rich, artistically designed place like a museum or gallery. Others proposed a more bare-bones multipurpose space or a black-box theater, thinking that these spaces left room for creativity but perhaps more closely resembled the resources teachers had to work with in their real classrooms.

From Workshop to Movement

The short-term goal of the team's Undisciplined Classroom is to inspire educators and give them tools to make their own classrooms cross-disciplinary. The longer-term goal is to spark institutional and systems change from the bottom up. In addition to benefiting teachers, the space would also be a petri dish in which to study the effects of blending disciplines in education. Undisciplined Classroom alums and their students could be tracked in follow-up studies.

Eventually, the Undisiplined Classroom concept could be taken on the road, spreading to other communities and finding a wider audience. A traveling workshop could reach underserved communities where interdisciplinary collaborations have the greatest potential to improve student engagement and learning.

The data gathered from the Undisiciplined Classroom could also someday inspire a set of best practices to help other teachers incorporate these practices into their classrooms. The team envisioned an associated online portal where teachers could share their strategies with an even broader audience.

Conclusion

The team noted the lack of available resources for teachers hoping to teach beyond disciplines, as well as the numerous system-wide constraints encouraging them to stick to scripted lesson plans. They agreed that the Undisciplined Classroom would be an innovative way to inspire teachers to break that mold while simultaneously providing a way to monitor the effects of such educational practices.

Innovation, Creativity, and Action

CHALLENGE

Herbert Simon once famously stated: "design like science is a tool for understanding as well as for acting." What might be examples of principles, methods, processes, and strategies of a successful art/design and science integration that may accelerate our ability to both innovate and act?

SUMMARY—GROUP 1

Kevin Morris, NAKFI Science Writing Scholar
Emory University

Let's dance. The team was asked to use creativity, innovation, and action to generate a project that bridges art and science in a substantial way. In doing so, the group decided to "unveil" the power of dance and validate the cultural, health, and psychological benefits that dance has on individuals and communities. This project would integrate mind and body through dance to enhance the capacity for groups of individuals to navigate the path through complex issues in a way that is collaborative and relatively free of friction. In addition, this project would further highlight the advantages that result from using dance as more than just an art form.

The idea that dance has beneficial effects on individuals is not new. In fact, dance is commonly used to aid in the treatment of a variety of diseases, reduce stress, and influence cultural change. Consisting of members from

the dance community, the group was widely aware of the anecdotal benefits of dance but also the lack of rigorous studies that support these benefits. The group noted that there have only been a limited number of small-scale studies to support the beneficial effects of dance. These studies were often restricted to the individual physical health benefits of some dance forms. The lack of a large-scale study of the universe of dance and movement and its efficacy on individual and community health and well-being then emerged as the targeted issue of the group's focus. A project of this kind would lessen the divide between science and art, as it would scientifically test the parameters of dance on human problems.

In order to make this study as thorough as possible, the group needed a method that targeted a diverse group of individuals and incorporated a variety of different dance forms. After hours of debating, the group proposed an app-based approach to collect data on the benefits of any and all types of dance in a comprehensive, rigorous, and innovative way. This proposal utilizes citizen science and crowd-sourced methods to collect data on individuals of all ages and nationalities who are participating in dance. These self-reported data would then be analyzed to measure the impact of dance on an individual's overall health and well-being. This large-scale data collection would constitute the first phase of the study. The second phase would consist of an onsite study that measures how dancing affects individuals in a workplace or classroom setting. The greater lessons from this study could extend far beyond dance. Although focusing on dance, this idea has the power to serve as a template for measuring the benefits of different types of art forms, such as musical or theater arts, on individuals.

For the first phase of the project, the group wanted to employ a technology that is easy to use and familiar to diverse groups of people. Drawing inspiration from current culture, the team adopted the premise that an app located on people's smart devices would be appropriate. The app enables everyday people to collect data on the effect dancing has on others. By partnering with businesses, hospitals, schools, and other institutions or organizations, the group will expand its resources for the study and maximize participation. Individuals would enroll in the study by downloading the app and creating a profile. Participants would then self-report their frequency and type of dance, along with indicators of their biological, psychological, and social well-being. The study would also take advantage of digital technologies to automatically monitor aspects of health such as heart rate or sleep quality. All of this information would be synchronized with the self-reported data into the app, allowing for a comprehensive analysis.

As a second phase of the study, the group wanted a way to take all of the acquired data and test the efficacy of the study in a controlled environment. This pursuit would be accomplished by complementing the group's citizen science project with a study at a place-based study. Using an environment such as a workplace or a classroom, the group envisions incorporating a structured dance program into the routine of the individuals. The group can then measure the same biological, psychological, and social aspects that were reported in phase one. In doing this approach, the citizen science data can be compared to the environmental data in phase two. The major ability of phase two would be the ability to extend the study to evaluate the use of embodied learning on individuals' performance and their interaction within a group.

An extended phase of this study would be the establishment of permanent dance centers in need-based areas. These areas include underserved communities and schools but also work environments that could benefit from the use of dance. These dance centers would implement a curriculum that would be derived from the data collected from the study. A person would enroll in the center and be given a dance program to help alleviate problems and better navigate personal challenges. Use of these centers would improve the overall health and well-being of a workplace or a community.

All in all, the team sought to unveil the power of dance by creating a scientific measure of the benefits of dance. The major and most immediate outcome of the project is a data-driven description of the impact of dance. With strategic implementation, this assessment can be used to spark institutional and personal change. By validating the benefits of dance, this study has the power to also restructure the way institutions visualize and use dance. A hope of the group would be to create a society where institutions establish a common practice to include dancers in business teams, city councils, or schools. On a personal level, individuals will learn to regularly use dance as a method to fight workplace stagnancy, disease, and social isolation. By reuniting the mind and body through dance, individuals will learn new ways to navigate through the complex social and personal issues that confront them.

Innovation, Creativity, and Action

CHALLENGE

Herbert Simon once famously stated: "design like science is a tool for understanding as well as for acting." What might be examples of principles, methods, processes, and strategies of a successful art/design and science integration that may accelerate our ability to both innovate and act?

SUMMARY—GROUP 2

Chris Patrick, NAKFI Science Writing Scholar
Johns Hopkins University

Michele Besso was a close friend of Albert Einstein. As a young man, Einstein and Besso, an engineer, took long walks and talked. The companions would work through problems with each other. It was Besso who introduced Einstein to the work of Ernst Mach, which ultimately influenced Einstein's approach to physics. Einstein called his friend Besso "the best sounding board in Europe."

This team on Innovation, Creativity, and Action considered examples of art-science integration that could accelerate the public's ability to both innovate and act. These examples were to echo the sentiment of Herbert Simon when he said, "design like science is a tool for understanding as well as for acting."

In response to this prompt, and with the story of Einstein—a creative

genius—and his friend Besso in mind, the team wondered, "What if everyone had their own Besso?"

Consequently, the team developed a "virtual Besso," a creativity tool. The goal of a creativity tool is to accelerate the birth of novel ideas. The team thinks that a creativity tool should also provide emotional support and encouragement, facilitate divergent thinking, and foster collaboration among individuals. Virtual Besso would be a program that provides users with a creativity-enhancing companion and sounding board.

The same way that Einstein and the real Besso walked together, virtual Besso, an augmented reality program, would provide creative guidance to a user while they walk. Using augmented reality glasses, Besso would offer users visual and auditory stimulation that might enhance their creativity.

On a walk, a user would be able to converse with Besso. A user's conversation with Besso would prompt the appearance of visual stimulation via augmented reality glasses that would enhance a user's immediate surroundings with graphics superimposed on the natural environment. These graphics would be linked with elements in a user's environment, synched in a way that integrates the augmented images into a user's immediate surroundings. Depending on where a user chooses to walk, images may blossom from a flower or wash up with waves on the shore. Images would appear and disappear gracefully, perhaps flowing in and out of a user's vision in tandem with moving elements in the environment.

A user would also be able to see Besso's shadow with the augmented reality glasses. The form a Besso's shadow takes would depend on its user, as a user would be able to personalize Besso to their liking. A user's Besso may take the form of a human or an animal, whichever a user prefers. A user could also individualize Besso's personality.

The personalization aspect of Besso functions to make this program adaptable to a wide audience, from researchers to 12-year-old students—to anyone, really.

Besso is meant to provide a user with emotional support, encouragement, and companionship—all components of a supportive, creativity-enhancing environment.

The team decided that divergent thinking is also key to enhancing creativity. Besso fosters divergent thinking by working like an indirect search engine. A user could tell their Besso one or several key words, and their Besso would present images, text, and auditory stimulation related to—but not exactly matching—these key words. Users could then follow an associative trail of ideas away from their original search terms. Besso's indirect

search engine would serve to make unexpected connections between topics for a user. Besso would storyboard this process of divergent thinking, keeping track of a user's history. Users would be able to visit their past searchers and paths of thought.

Users would be able to share their storyboards with other users. The process of sharing storyboards is meant to encourage collaboration between users. The Seed Team envisions Bessos across the world linking together according to their users' common or complementary interests to make connections between users. Bessos would introduce users in the hopes of spurring collaboration. The team envisions users' Bessos forming a worldwide network or "invisible college" that brings together creative thinkers from many different fields.

The team decided the best way to test the effectiveness of Besso would be with middle school students. Middle school students would be given a creative writing assignment. Half of the students would take a walk with Besso to discuss their assignment; half would not. Graders would evaluate the students' assignments for creativity to see if those who had walked with Besso produced more creative assignments.

This testable example illustrates the potential usage of Besso in schools. Team members believe Besso may be a potential solution to education inequality, specifically in mitigating the lack of creative mentors in underserved youth.

Ultimately, the team envisions Besso not only as creativity tool for students, but a creativity-augmenting companion for many audiences.

Harnessing Computers Worldwide to Address Urgent, Global Issues

CHALLENGE

"Citizen science" or "crowd-sourced" science will become increasingly important as a valuable means of harnessing the "world brain" to address critical social, ecological, or cultural issues. For example, many woodland, grassland, and shoreline areas remain to be ecologically assayed in ways that could be done by minimally trained citizen scientists. This could not only lead to benchmarks for species survival and climate change but also to increasing public awareness of the challenges through direct involvement. How can artists, designers, scientists, engineers, and medical researchers forge a lasting and effective alliance to enhance these efforts?

SUMMARY

Roberto Molar Candanosa, NAKFI Science Writing Scholar
Texas A&M University

"Harnessing the World Brain to Address Urgent, Global Issues" requires access to the minds of billions of people worldwide in an attempt to provide human intelligence to solve tasks that might be too complicated even for the largest computers. This network of brainpower is the global brain, a concept that serves as the namesake for the proposed smartphone app called G-Brain.

Overpopulation is an urgent and global issue closely related to eco-

nomic development, one of humanity's great challenges. The team viewed economic opportunity and G-Brain as an optimal way to access the global brain. The app seeks to provide technological tools and connectivity as a way to harvest brainpower and enable people worldwide to participate in the knowledge economy. This is an idea that has been implemented in many ways during the past decade or more as access to smart phones has become widespread in many rural areas of the world.

G-Brain, like other apps, would pay people modest amounts of money to contribute their time to different types of projects—some of which could help scientific advancement. The app's ability to access data from the input of billions of people could be analyzed to develop information that might prove useful when addressing urgent global issues.

Although some team members differed in opinions regarding the ultimate purpose of G-Brain, the team conceded that this app as a business platform that could potentially help developing countries, while making money for the app-maker as well. However, the app is not unlike other platforms that already exist. What the team proposed is enhancing a working prototype that a team member already tested in villages of Africa. G-Brain would use a system similar to the crowd-sourcing Internet marketplace Mechanical Turk, which allows businesses or people to request workers from anywhere in the world. Mechanical Turk enables people to complete repetitive tasks such as analyzing items from shopping receipts, typing text from certain images, or transcribing data—all tasks that currently require human intelligence.

G-Brain would be rolled out the way other phone apps are. The app could facilitate access to people in both developed and developing countries, as long as people are connected to the Internet. G-Brain would be an interface that would allow anyone anywhere to get work that is low paying by U.S. standards. Workers at the other end of the app would choose from various tasks and complete them in exchange for a modest monetary compensation set by the businesses or organizations that want data. G-Brain could be a source of income for people in developing countries. Examples of potential G-Brain workers from developed countries include teenagers or retirees in need of income.

G-Brain would be based on a sustainable model that would ensure a lasting and effective business platform. The human computational power accessed through G-Brain would be inclusive enough to do simple and complex tasks.

While G-Brain could do simple tasks, the app would also be powerful

enough to do more complex tasks. The team envisioned the app to be an asset for fields that yield large amounts of data. For example, a team member described an example in which an app like G-Brain would be helpful based on an experience he had when crunching bioinformatics data with real-human computational power. He said there are all kinds of bioinformatics data that get lost in the literature because they are images of biochemical pathways. The working prototype he described harvested brainpower from African villagers and turned those images into metadata. The villagers were trained to recognize biochemical patterns with a level of accuracy similar to that of doctoral students in the field, but the African workers were paid far less than doctoral students in the United States. That team member also said tasks for which researchers usually struggle to compensate workers would be more accessible with G-Brain, because the app would outsource work to people that could potentially benefit from modest compensations while the company makes a profit.

Other complex instances in which the team envisioned G-Brain could be useful include the following hypothetical situations:

- Using human workers to speed up current methods of analyzing satellite images to locate various things, such as a missing airplane
- Using human workers to facilitate mapping of damaged areas after natural disasters
- Using human workers to count the number of open windows within a given area to analyze relationships between possible air exchange, pollution levels, and incidences of certain diseases

Some tasks with G-Brain would require instant, live interaction between task requesters and workers. For example, a team member suggested that G-Brain could be useful in emergencies where a crisis overwhelms healthcare providers, thus affecting their ability to triage patients effectively. In such a scenario, G-Brain workers would provide instant feedback to help healthcare providers assign different degrees of urgency to patients and decide which patients require immediate assistance.

Depending on the task at hand, G-Brain would need robust computing and user-friendly interfaces to work. But essentially, the app would only need smart phones and Internet to connect data collection requests with workers. Some team members expressed their concern about the feasibility of G-Brain to be used in tasks requiring instant feedback, particularly thinking of workers living in developing countries. However, a member of the

team said connectivity would not be a limiting issue, because smart phone use and Internet access are increasing tremendously fast worldwide. This team member, who is promoting G-Brain, also explained that in rural communities lacking the technology to access G-Brain, groups like Engineers Without Borders or other well-established philanthropic organizations could set up the connectivity needed. Thus, G-Brain would see groups that are already embedded worldwide as strategic partners. And these groups would also serve as points of reference for the urgent and global issues that G-Brain would address.

In conclusion, the team agreed that the G-Brain smart phone app, or something very much like it, would be useful as a way of gathering large quantities of data that require human input.

Developing Art-Science Collaborations to Reduce Cross-Cultural Denialism

CHALLENGE

Cross-cultural science denialism will continue to impede progress on urgent, global issues such as innovation in healthcare, climate change, and sustainable food supply. How can art and science combine to confront the entrenched views of those who are too often simply dismissed as "science deniers," when these views are driven by perceived legitimate fears and concerns? How can interdisciplinary projects, exhibits, or shows further progress toward ameliorating entrenched controversies? What can art add to the science of science communication and public engagement?

SUMMARY

Iveliz Martel, NAKFI Science Writing Scholar
Texas A&M University

The team was challenged with developing art-science collaborations to reduce denialism on scientific issues. The group came up with the idea of creating a program in which artists and scientists work together to better inform the public on important issues in science, by offering artists the opportunity to spend at least 2 weeks in-residence at a research center and receive a stipend to subsequently develop original, creative ways to present science to a lay audience. The goal behind this idea is "to empower artists

to spark conversations that have been broken within their communities," the proposal says.

The *Oxford Dictionary* defines a denialist or denier as "a person who does not acknowledge the truth of a concept or proposition that is supported by the majority of scientific or historical evidence." Denialism has been described as the use of rhetorical arguments to create false debate that appears to be legitimate but in reality such a debate or controversy doesn't exist. By using false claims, deniers refuse scientific evidence, generate disagreements against scientific consensus, and distract the public from helpful and informative conversations about science. Experts on anti-science movements describe deniers' claims as emotionally appealing but lacking evidence.

Among scientists, some think that they do not have to spend time arguing with deniers, who are usually not interested in having a constructive discussion. Instead, they should focus their efforts on dealing with people who want to be "honestly informed." Others, such as the researcher Baruch Fischhoff, have looked at the role of science when dealing with denialism. He has suggested that the goal of science is not looking for agreement, rather looking for "fewer and better disagreements." In this sense, having scientists involved in outreach seems crucial to foster an effective public engagement and constructive debate in science.

The team thinks its proposal goes in the direction of promoting a constructive discussion about science issues by encouraging scientists and artists to work together, reach the public outside science, and generate spaces of conversation and education.

The goal is to set up a call for artists to propose a project that engages their communities in a conversation around hot-button issues in science. This initiative intends to encourage artists to come up with ideas rather than leaving it to scientists to address the public's concerns. As well, the team speculated it must be tough for scientists to think of ways to reach people outside science when they spend much of their time in their labs. That is the thinking behind the proposal to encourage artists to tackle hot-button issues in science.

Because artists applying to this program will come from the local community, one can suppose they will have a different view of the needs, beliefs, and worldviews of their communities than do scientists. Thus, artists will have the freedom to suggest an art project that effectively draws their communities into a conversation and convey people's opinions about controversial topics. Some issues artists might address are whether routine vaccination

is safe, whether climate change is leading to "global change" that manifests itself in many ways, such as mass migration of human populations, and the changes we might anticipate in food resources. "Global change" is a concept that better describes the varied impacts global warming can have on different communities; as mentioned previously, it can cause migration problems, for example. Even though migration is a social issue, it will worsen because of sea level rise, which is a consequence of climate change.

These art projects may be exhibitions, science kits, games, tools, activities, or whatever artists think is the best way to help the dialog. Artists will also have to define the audience and specific community they want to reach with their projects.

Hot-Button Issues

The team recognizes that the debate around these hot-button issues is challenging, and in many cases it is difficult because of intolerance, lack of knowledge, or public fear of science. That is why the team believes that it is necessary to reach communities with a creative, artistic approach that is complementary to data offered by the scientific community.

In that sense, the team proposes facing doubt and controversy through an integrative perspective, different from what the information deficit model suggests. The deficit model assumes that people don't know about science, and their ignorance is the main cause of their hostility to science, whereas the team recognizes that other factors such as beliefs, worldviews, previous experiences, and community context also play a role in forming people's views of the world.

Familiar Spaces

Ideally, artists will identify a "familiar space" in the community where the discussion of hot-button issues will take place. A familiar space can be a community garden, a school, a grocery store, a market, etc. These places share common characteristics: they are known by people, part of their daily lives, and located within their communities, and they already exist. In other words, these places are different from labs and art galleries, which are scientists' and artists' familiar spaces.

The idea of reaching people in a community context was inspired by the initiative the Physics Bus, which contains electronic debris for children to explore when the bus visits schools in the United States. The Physics Bus

is a space in which the general audience approaches science without the fear of "breaking something" because devices inside the bus are already broken, and children can freely interact with those appliances.

Other existing programs also encouraged the team to foster the idea of familiar spaces, for instance, the work done by the artist Miriam Simun. She created GhostFood, a food trailer that was located on busy streets (familiar spaces) of cities such as New York. GhostFood offered "scent-food" to the public. The experience involved inhaling particular foods' scents (cod, peanut butter, and chocolate) while eating ingredients that imitated the texture of real food. Thus, the public could taste "illusions of food" and approach food in a different way. This experience made them think, for example, about food scarcity. In this case, the public was invited, not forced, to try these "illusions of food" and peek in the consequences of global warming on their daily lives in the future.

Why Art and Artists

Several initiatives have shown that art in collaboration with science can address hot-button issues. In 2001, for example, British artist David Buckland launched project Cape Farewell that for more than a decade has taken artists, filmmakers, writers, and climate scientists in expeditions to places such as the Andes, the Amazon, and the Arctic. Cape Farewell has allowed artists to gather material to inspire their art works by visiting places that are being threatened by global warming and can drastically change because of climate change. Another example is the documentary *Chasing Ice* that in 2012 showed poignant images of how fast glaciers are thawing in the Arctic—images we now see often in the news in print and online. Both projects used art as a mediator to communicate science, tackle public hostility toward scientific evidence on climate change, and face people who do not believe that human activity has caused climate change.

Initiatives such as Cape Farewell are based on the idea that science and culture are closely related because artists are likely to be trusted by their communities. Artists know how to represent people's values and fears, beliefs, and attitudes toward science. This group believes that art can narrow the distance between the public's personal world and evidence by appealing to people's emotional identification with science issues, as the Physics Bus and GhostFood projects have done.

In one of the sessions, the team specifically thought about whether it is possible to change people's minds by appealing to them with more than

data. As part of the discussion, members listened to the episode "The Incredible Rarity of Changing Your Mind" from the radio show *This American Life.* The episode tells the story of a person who changed his opinion on gay marriage after being visited by a gay man who shared the obstacles he has overcome for being gay. The conversation seems to have made the citizen rid himself of some views he had regarding gay marriage.

In that sense, the team thinks artists and their ability to represent different views in creative ways can effectively appeal to people's emotional identification and help clarify misinformation around controversial issues. As well, art-science collaborations can enhance "fewer and better disagreements" in science, as Fischhoff suggested the goal of science is.

Based on these ideas, the team's proposal aims to give agency to artists to address hot-button issues in science through art projects. To better accomplish that objective, the program will give artists the unique opportunity to experience science with scientists in their labs through a residency of at least 2 weeks. It will also provide scientists with the opportunity to learn more about the creative process of art by working directly with artists.

Generating Projects That Bring Together the Structure and Systems Between Biology and Art to Create Either Biology or Art

CHALLENGE

In science and the arts, creativity happens at the edge of the known, fostered by its milieu, the environment in which it is allowed to grow. Human growth, for example, from fetus to baby to adult occurs in the right milieu, with pleuripotential stem cells modifying their function based on their environment. In the larger world, the greatest biodiversity is seen at the "edge" between forest and savannah. Are there tangible projects that can be created between the artist and biologist to embrace this concept?

SUMMARY

MaKendra Umstead, NAKFI Science Writing Scholar
Emory University

The goal of scientific research is to illuminate the unknown areas of a particular field. Unfortunately, though, scientific discovery can be hindered by limitations in technology, singularity of thought, and simply "not knowing what is unknown." What goes unnoticed may actually be the content that holds the key to innovation. With this notion in mind, the team considering biology and art at the 2015 National Academies Keck *Futures Initiative* decided to focus on "Seeing the Unseen." The team wants to the catalyze creativity and inspiration by bringing together the distinct yet shared approaches of science and art. This summary showcases the most relevant highlights from its work.

"L'essentiel est invisible pour les yeux."
What is essential is invisible to the eye.
—*The Little Prince*

"Seeing the unseen" in order to advance scientific discovery requires researchers to expose underlying assumptions in their research that that go unapproached or questioned. Like many scientists, many artists in visual, digital, and performing art seek out the unresolvable. Combining the creative processes of art and science may be well suitable for this task.

A Catalyst to Innovative Thinking: Making the Invisible, Visible

The Problem

In order to catalyze scientific exploration into parts unseen, the team looked for an avenue to combine art and science.

The Idea

A Web-based portal to connect artists desiring to work on innovative projects and scientists wanting to try a new approach to research challenges would bring the two groups together by creating a virtual space where interested parties can form a community, and artists and scientists would have an opportunity to engage in a collaborative experience. Artists and scientists that connect in the virtual space would be encouraged to have face-to-face interactions in which they explore the unseen and unknown areas of a particular scientific question.

The Approach

Interested scientists and artists would register for the website and search for individuals who want to form a collaborative team. Based on mutual interests or even experience level, digital interactions will turn into dialogues between artists and scientists. Scientists would be asked to try and identify the assumptions made in their research and artists will interpret and convey the concepts using their own methods. In addition, the artist and scientist would have the freedom to define their preferred collaboration method, potentially taking the form of an artist in residence or an international partnership.

The Outcome

By documenting the collaborative experience by film, photography, and text, the connections and insights that result for both the artist and scientist working together will be made visible in a pop-up exhibition at the culmination of the project. The pop-up installation will be strategically planned to exhibit in unexpected locations where art is not normally seen. The goal of the exhibition is to create an interactive social experience with an opportunity to collect data from a diverse audience and to create a transformative experience for the researchers, the artists, and the public. Accessibility of the information about science and art is a major component of this initiative. One additional layer of seeing the unseen is providing an opportunity for the public to engage in topics they may not usually encounter. A long-term goal of this initiative is to collect a series of successful collaborations for viewing as a Public Broadcasting System (PBS) documentary or a traveling exhibit for arts and science museums, showcasing what happens when the two worlds of art and science collide.

Transformative Collaborations and Human Experiences

"Want to know how paramecium have sex?" one team member asks another. Not a typical lunchtime conversation by any means for an architect and art historian, but they entertained the biologist who was explaining his research and detailing the ambiguous problems in his field and decided to put their concept of connecting scientist and artists to the test. The scientist explained the conundrum of multi-nucleated, single cellular organisms. After viewing slide after slide of two-dimensional plants, the architect began to draw. Trees. Dimensions. Shapes. Then, the architect summoned the biologist for a walk. While picking up branches and sculpting, he shared an insight with the (now skeptical) biologist: instead of biasing interpretations based on the forward view of the organism shown on PowerPoint slides, perhaps looking at it from the top view would transform thinking and conclusions. This insight clicked with the scientist. Their walk had led to a hill overlooking the city of Irvine, California. The rivers, the streets, the topology, all looked different from the top of the hill. Perhaps his work was missing insights because of the very planar view taken in the past. What could he see by looking from a different perspective?

The team members shared their experience and the branch sculpture with conference attendees. Their exhibition emphasized that the collabora-

tion pushed the scientist outside of his comfort zone, provoking him to see his own work through the artist's eyes.

Innovation Is Never Without Challenge

The team realized that the innovative collaborations between artists and scientists would not happen without challenges. From the scientist perspective, how could the outcomes from these human experiences be measured? How many scientists have the time and interest to actually get engaged with an initiative such as this? From the artists' perspective, could scientific topics be presented in a way that artists would understand? Does quantifying the human experience after an exhibition take away from the significance of the art? Both fields determined that communication between the artist and scientist would need to be negotiated such that neither infringed on the other's creative process. The scientist may strive for accuracy while an artist's goal is creativity. Furthermore, team members found it essential that art was not used as a servant to science, but that the experience should be mutually beneficial for both science and art.

Conclusions

The team explored why certain matters are left ignored, unexplored, and labeled as junk, and looked for ways to open avenues to probe those areas using a different medium. By exploring scientific unknowns through the vehicle of artistic collaboration, the team proposed that through a Web-based platform for connecting artists and scientists, the community could be compelled and inspired to do the same. As an artist stated during a meeting, "As an artist, I can take a big problem and represent it in a form that people can interact with and relate to. . . . I'm not [necessarily] trying to propose a solution . . . but to make the problem more visible." In areas where scientists may seek to eliminate variables and find the simplest explanation for data, artists may be able to expand the question beyond the confines of the experiment. By combining art and science perspectives to encourage cross-pollination of thought, the potential to enhance both scientific thinking and artistic expression is unlocked and the unseen can be visualized.

Creating Human-Centered Cultures with Human-Centered Technologies

CHALLENGE

How can we create human-centered cultures with human-centered technologies to address our needs, improve our environment, and/or make government decision making more transparent? How do we create technologies that are not only accessible to diverse populations, including those who are not tech-savvy, or those who are isolated, but technologies that respond well to empathy, collaboration, and inspiration?

SUMMARY

Vanessa Cox, NAKFI Science Writing Scholar
Georgia Institute of Technology

The team, focused on creating human-centered cultures with human-centered technologies, discussed possible ways to use technology to promote empathy. Too often, rather than broadening people's viewpoints, modern technology reflects people's own opinions, views, and biases back to them, an effect known as the echo chamber. The team wanted to use technology to decrease isolation, broaden people's views, and promote empathetic responses to opposing viewpoints. In effect, the team proposed to use technology to allow people to escape the echo chamber.

The echo chamber is the idea that by reflecting people's ideas and opinions back to them, technology is reinforcing people's personal views rather

than exposing them to a wide range of viewpoints. For example, Internet search results and advertisements are customized based on previous websites visited. Similarly, social networks surround people with friends who generally share their world view. By creating an environment in which people encounter different viewpoints less frequently, the echo chamber can lead to decreased empathy. The team thinks this is a significant social problem because decreased empathy can inhibit people's ability to collaborate and solve complex problems, whether locally, nationally, or globally.

The group considered what promoting empathy might look like. One idea is to create an experience that would allow someone to step into someone else's skin and feel what someone else is feeling. Could such an experience give someone a better understanding of why different individuals have different points of view? Could it help develop greater empathy for others? Would it ultimately teach people more about themselves?

While researching this topic, the team found useful information from an experimental installation. The Gray Mirror, by Jose Colucci, was designed to encourage young people to make decisions that would help them later in life. With the goal of building empathy for their older selves, young people see images of themselves that have been artificially aged. The purpose of the installation is to give participants the opportunity to empathize with their future selves with the hope that this will encourage them to invest in their long-term health and financial stability. In effect, this would establish socially useful empathy for oneself.

The team's concept expanded upon this idea. They conceived of an immersive installation with the goal of promoting greater empathy for others. This installation, which the team plans to call the Asymmetric Mirror, would reflect an alternate version of the participants with the goal of opening their eyes to the viewpoints and experiences of other people. The team decided the Asymmetric Mirror would involve three experiences, sight, touch, and sound, which would use existing technology as well as technology in development to engage multiple senses while exploring how technology can be harnessed to induce an empathetic experience.

The first encounter with the Asymmetric Mirror center would focus on the idea of stepping into someone else's skin and seeing what that person sees in the mirror. In this experience, the participant's face would be recorded, and facial mapping technology would allow her to see a modified image of what she would look like as a person of a different age, gender, or ethnicity, thereby stimulating empathy for people who have a different appearance.

The second experience would enable someone to physically feel what it is like to be is someone else's body. In this part of the installation, the participant would wear a biometric jacket, which would impart someone else's physical response to a video clip. The biometric jacket would use haptics, such as vibrations and temperature to impart the feeling of someone else's heartbeat, breathing, and muscle tension. The team wants to learn whether feeling someone else's physical response changes how a person feels emotionally and if it can ultimately teach her something about herself.

The third experience would build on the first and second by allowing a person to hear someone else's thoughts. The participant would watch a synthesized video clip of herself espousing an opinion she does not believe and has never voiced. Simultaneously, a biometric jacket would allow her to feel the physical response of someone who agreed with the opposing statement. The team wondered if the experience of watching herself voice an opposing opinion would engender greater empathy for people who disagree with her.

In this part of the installation, the same facial mapping from the first experience would be used but voice mapping would be added. The participant would select and read a short text expressing an opinion she agreed with. During this process the participant's face and voice would be recorded. Then, using facial mapping techniques and voice modification technologies, a computer would create a video of the participant espousing the opposite viewpoint, one she personally does not hold, on the same topic. The team discussed the importance of each viewpoint being a thoughtful, logical statement, rather than an unreasonable emotional outburst.

The team plans to reveal the installation at South by Southwest Interactive, an interactive media conference, where the audience is likely to be aware of the echo chamber and will be excited to try this type of technology-based experimental installation. Because widespread availability is a priority for the team, they also discussed the development of a smart phone app to create empathetic experience.

Appendixes

Preconference Tutorials

Each participant had varying levels of knowledge on the topics included in this year's conference. To help create a common language for the meeting, participants were asked to engage in pre-conference learning and to participate in a pre-conference activity related to their seed idea team.

OBSERVATION ACTIVITY

In addition to reviewing tutorials related to the overall conference and seed ideas, attendees were asked to "do" or "observe" something related to their assigned seed idea prior to the conference. The purpose of this exercise was to help participants identify what the problem meant to them and how it fits into a larger context. Participants shared their experiences with their seed idea team members on the first day of the conference. Examples included observing and documenting a visit in a healthcare setting as a patient or volunteer (seed idea C); taking an outdoor yoga class and journaling the experience (seed idea E); visiting a farm-to-table restaurant to uncover details about the origins of ingredients in food (seed idea G); or participating in a citizen science project (seed idea K).

Attendees were asked to consider the following to help them choose what they wanted to focus on for this pre-conference exercise:

1. An activity that directly relates to their assigned seed idea. Alternatively, attendees could choose an activity that would help

them gain insight into how someone with a different perspective/background views the seed idea (e.g., scientists working on a challenge about the human microbiome could attend an art installation that uses bacteria as an artistic material).

2. Documenting the activity through journaling, taking photos or video, blogging, etc., to help attendees remember the experience and share it with their teammates at the NAKFI conference.
3. Reflecting on the experience by taking a step back after the activity to get a sense of the big-picture "take-aways": did this experience help the attendee uncover anything about the seed idea that's interesting, inspiring, or especially problematic?

Preconference Inspiration Tutorials provided inspiration for the conference through stories about art-science "aha" moments, innovation and creativity, and a behind-the-scenes look at planning the 2015 NAKFI conference. Seed Idea Tutorials related to the individual seed ideas and were intended to inspire creative thinking about these ideas.

PRECONFERENCE INSPIRATION

"Interview with NAKFI Steering Committee Chair David Edwards." An interview with NAKFI Steering Committee Chair David A. Edwards about creativity, innovation, and planning for the 2015 NAKFI Conference.
https://soundcloud.com/user-807744834/interview-with-nakfi-steering-committee-chair-david-edwards

"A History of the Concept of Creativity." A presentation by Richard N. Foster, co-chair, National Academies of Sciences, Engineering, and Medicine's Presidents' Circle.
https://youtu.be/_8FGhla1hNg

"Rethinking the Norm in Pediatrics." An interview with David Yager, Dean of Arts, Distinguished Professor, University of California, Santa Cruz, and George Dover, Given Professor and Director, Department of Pediatrics, Johns Hopkins Children's Center.
https://soundcloud.com/user-807744834/rethinking-the-norm-in-pediatric

"The Three-Body Project." An interview with Greg Laughlin, professor, physical and biological sciences, University of California, Santa Cruz, and Ted Warburton, professor, dance, University of California, Santa Cruz.
https://soundcloud.com/user-807744834/the-three-body-project

"AHA Moment: Cell Tower." Studio360 Interview with Steering Committee Member Don Ingber, Director, Wyss Institute for Biologically Inspired Engineering at Harvard University; Judah Folkman Professor of Vascular Biology, Harvard Medical School and Vascular Biology Program, Boston Children's Hospital; Professor of Bioengineering, Harvard School of Engineering and Applied Sciences, Wyss Institute. One day he saw a piece of modern sculpture and—Eureka!—he was inspired to make a major breakthrough in biology. Lu Olkowski reports on the unlikely epiphany.
https://www.wnyc.org/widgets/ondemand_player/studio360/#file=%2Faudio%2Fxspf%2F106750%2F

"The Power of Serendipity" CBS News Story. There is nothing like starting off with a bang. In 1867 Alfred Nobel accidentally discovered dynamite after putting a popular but flammable salve on a cut finger. Call it serendipity.
http://www.cbsnews.com/videos/accidental-inventions

"Why Truly Innovative Science Demands a Leap into the Unknown" by NAKFI Alum Uri Alon. While studying for his Ph.D. in physics, Uri Alon thought he was a failure because all his research paths led to dead ends. But, with the help of improv theater, he came to realize that there could be joy in getting lost. A call for scientists to stop thinking of research as a direct line from question to answer, but as something more creative. It's a message that will resonate, no matter what your field.
https://www.youtube.com/watch?v=F1U26PLiXjM

"How to Manage for Collective Creativity" TED Talk by Margaret Hill. What's the secret to unlocking the creativity hidden inside your daily work, and giving every great idea a chance? Harvard professor Linda Hill, co-author of *Collective Genius*, has studied some of the world's most creative companies to come up with a set of tools and tactics to keep great ideas flowing—from everyone in the company, not just the designated "creatives."
http://www.ted.com/talks/linda_hill_how_to_manage_for_collective_creativity

"How to Live Before You Die" TED Talk by Steve Jobs. At his Stanford University commencement speech, Steve Jobs, CEO and co-founder of Apple and Pixar, urges us to pursue our dreams and see the opportunities in life's setbacks—including death itself.
http://www.ted.com/talks/steve_jobs_how_to_live_before_you_die

"Be an Opportunity Maker" TED Talk by Kare Anderson. We all want to use our talents to create something meaningful with our lives. But how to get started? (And . . . what if you're shy?) Writer Kare Anderson shares her own story of chronic shyness, and how she opened up her world by helping other people use their own talents and passions.
http://www.ted.com/talks/kare_anderson_be_an_opportunity_maker

"Why It's Time to Forget the Pecking Order at Work" TED Talk by Margaret Heffernan. Organizations are often run according to "the superchicken model," where the value is placed on star employees who outperform others. And yet, this isn't what drives the most high-achieving teams. Business leader Margaret Heffernan observes that it is social cohesion—built every coffee break, every time one team member asks another for help—that leads over time to great results. It's a radical rethink of what drives us to do our best work, and what it means to be a leader. Because as Heffernan points out: "Companies don't have ideas. Only people do."
http://www.ted.com/talks/margaret_heffernan_why_it_s_time_to_forget_the_pecking_order_at_work#t-76038

National Endowment for the Arts. How Creativity Works in the Brain.
http://arts.gov/sites/default/files/how-creativity-works-in-the-brain-report.pdf

SEED IDEAS

Machines and the Human Biome at the Frontier of Medicine Science

Video

"How Our Microbes Make Us Who We Are" TED Talk by NAKFI Alum Rob Knight. Rob Knight is a pioneer in studying human microbes, the community of tiny single-cell organisms living inside our bodies that have a huge—and largely unexplored—role in our health. "The three pounds of microbes that you carry around with you might be more important than every single gene you carry around in your genome," he says. Find out why. https://www.ted.com/talks/rob_knight_how_our_microbes_make_us_who_we_are?language=en

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Aagaard K, Petrosino J, Keitel W, Watson M, et al. The Human Microbiome Project strategy for comprehensive sampling of the human microbiome and why it matters. *The FASEB Journal* March 2013;27(3):1012-1022: http://www.fasebj.org/content/27/3/1012.

Grogin D. Microbes in the gut are essential to our well-being. *Scientific American* 2015;312(3): http://www.scientificamerican.com/article/microbes-in-the-gut-are-essential-to-our-well-being.

Hafezi H, Robertson TL, Moon GD, et al. An ingestible sensor for measuring medication adherence. *IEEE Transactions on Biomedical Engineering* Jan 2015;62(1):99-109: http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=6861446.

Kembel SW, Jones E, Kline J, et al. Architectural design influences the diversity and structure of the built environment microbiome. *The ISME Journal* 2012;6:1469-1479: http://www.nature.com/ismej/journal/v6/n8/full/ismej2011211a.html.

National Institutes of Health. The Human Microbiome Project: http://hmpdacc.org.

Owyang C, and Wu GD. The gut microbiome in health and disease. *Gastroenterology* May 2014;146(6):1433-1436: http://www.gastrojournal.org/article/S0016-5085%2814%2900381-3/abstract.

Schwartz A. The future of medicine is in devices you swallow. *Fast Company* 14 Jan 2014: http://www.fastcoexist.com/3024773/worldchanging-ideas/you-will-swallow-a-sensor.

Skidmore G. Ingestible, implantable, or intimate contact: How will you take your microscale body sensors? *Singularity Hub* 13 May 2013: http://singularityhub.com/2013/05/13/ingestible-implantable-or-intimate-contact-how-will-you-take-your-microscale-body-sensors.

University of Michigan Health System. It takes a village . . . to protect us from dangerous infections? *ScienceDaily* 23 July 2015: http://www.sciencedaily.com/releases/2015/07/150723092123.htm.

Yatsunenko T, Rey FE, Manary MJ, et al. Human gut microbiome viewed across age and geography. *Nature* 14 June 2012;486:222-227: http://www.nature.com/nature/journal/v486/n7402/full/nature11053.html.

Designing a Healthcare System That Promotes Learning and Caring

Video

"Learning Health Systems Overview" by Richard Payne, MD, John B. Francis Chair in Bioethics, Center for Practical Bioethics. https://www.youtube.com/watch?v=0azoNiasr44

"What If Our Healthcare System Kept Us Healthy?" TED Talk by Rebecca Onie. Rebecca Onie asks audacious questions: What if waiting rooms were a place to improve daily healthcare? What if doctors could prescribe food, housing, and heat in the winter? In this presentation, she describes Health Leads, an organization that does just that—and does it by building a volunteer base as elite and dedicated as a college sports team. http://www.ted.com/talks/rebecca_onie_what_if_our_healthcare_system_kept_us_healthy

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Effken JA. Toward a learning health community: Challenges and opportunities. *HIMSS* 2015;19(1): http://www.himss.org/ResourceLibrary/GenResourceDetail.aspx?ItemNumber=39764.

Etheredge LM. A rapid learning health system. *Health Affairs* 2007;26(2):107-118: http://content.healthaffairs.org/content/26/2/w107.full.

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Etheredge LM. Toward a science of learning systems: Health, agriculture, education, economics and more. *ResearchGate* 2015: http://www.researchgate.net/publication/275581478_Toward_A_Science_of_Learning_Systems_Health_Agriculture_Education_Economics_and_More.

Friedman C, Rubin J, Brown J, et al. Toward a science of learning systems: A research agenda for high-functioning Learning Health System. *Journal of the American Medical Informatics Association* 2015;22(1):43-50: http://www.ncbi.nlm.nih.gov/pubmed/25342177.

Learning Health Community. www.learninghealth.org.

National Academies Press Learning Health Series. http://www.nap.edu/catalog/13301/the-learning-health-system-series.

Tavernise S. Healthcare systems try to cut costs by aiding the poor and troubled. *New York Times* 22 Mar 2015: http://www.nytimes.com/2015/03/23/health/taming-health-costs-by-keeping-high-maintenance-patients-out-of-the-hospital.html?_r=1.

Imagining New Ways to Use Music in Education and Health

Video

"Arts in Medicine" by PBS Video. At Moffitt Cancer Center in Tampa, classical music and arts projects provide another facet of healing for cancer patients through the Arts in Medicine program. http://video.pbs.org/video/2365263318

"Biorhythm: Music and the Body" by Science Gallery Dublin. https://youtu.be/Apw335t5rfg

"The Healing Power of Music" by PBS News Hour. An unconventional approach to recovery and coping, music therapy is a field of medicine capturing new attention due to its role in helping Gabrielle Giffords recover from a gunshot. Correspondent Spencer Michels reports on the versatility of music in a medical setting, but the difficulty of quantifying its effectiveness. http://www.pbs.org/newshour/bb/health-jan-june12-musictherapy_02-27

"Inventing Instruments That Unlock New Music" TED Talk by Tod Machover and Dan Ellsey. Tod Machover of MIT's Media Lab is devoted to extending musical expression to everyone, from virtuosos to amateurs, and in the most diverse forms, from opera to video games. He and composer Dan Ellsey shed light on what's next. http://www.ted.com/talks/tod_machover_and_dan_ellsey_play_new_music

"Music Education for Creativity, not a Tool for Test Scores" by NPR. Advocates are pushing for the virtues of music education that canot be measured numerically. Accessed online August 25, 2015. http://www.npr.org/2014/02/18/279182075/music-education-for-creativity-not-a-tool-for-test-scores

Suggested Reading

Grantmakers in the Arts. Revisiting research: Champions of change. *GIA Reader* 2012;23(3): http://www.giarts.org/article/revisiting-research-champions-change.

National Institutes of Health. Strike a chord for health. *NIH News in Health* 2010: http://newsinhealth.nih.gov/2010/January/feature1.htm.

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Thaut M, and McIntosh G. Music helps heal the injured brain. *The Dana Foundation: Cerebrum* 2010*:* http://dana.org/Cerebrum/2010/How_Music_Helps_to_Heal_the_Injured_Brain__Therapeutic_Use_Crescendos_Thanks_to_Advances_in_Brain_Science.

Trappe H-J. Role of music in intensive care medicine. *International Journal of Critical Illness and Injury Science* 2012;2(1):27-31: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3354373.

Restoring Physical Intuition

Video

"Architecture That Senses and Responds" TED Talk by Carlo Ratti. With his team at SENSEable City Lab, MIT's Carlo Ratti makes cool things by sensing the data we create. He pulls from passive data sets—like the calls we make, the garbage we throw away—to create surprising visualizations of city life. And he and his team create dazzling interactive environments from moving water and flying light, powered by simple gestures caught through sensors. https://www.ted.com/talks/carlo_ratti_architecture_that_senses_and_responds

"How Not to Be Ignorant About the World" TED Talk by Hans and Ola Rosling. How much do you know about the world? Hans Rosling, with his famous charts of global population, health, and income data (and an extra-extra-long pointer), demonstrates that you have a high statistical chance of being quite wrong about what you think you know. Play along with his audience quiz—then, from Hans' son Ola, learn four ways to quickly get less ignorant. http://www.ted.com/talks/hans_and_ola_rosling_how_not_to_be_ignorant_about_the_world

"The Rise of Human-Computer Cooperation" TED Talk by Shyam Sankar. Brute computing force alone cannot solve the world's problems. Data mining innovator Shyam Sankar explains why solving big problems (like catching terrorists or identifying huge hidden trends) is not a question of finding the right algorithm, but rather the right symbiotic relationship between computation and human creativity. http://www.ted.com/talks/shyam_sankar_the_rise_of_human_computer_cooperation

"Why the Universe Seems So Strange" TED Talk by Richard Dawkins. Biologist Richard Dawkins makes a case for "thinking the improbable" by looking at how the human frame of reference limits our understanding of the universe. http://www.ted.com/talks/richard_dawkins_on_our_queer_universe

Suggested Reading

Becker K. Is quantum intuition possible? *Nova* 2014: http://www.pbs.org/wgbh/nova/blogs/physics/2014/07/quantum-intuition.

Brownlee J. MIT invents a shapeshifting display you can reach through and touch. *Fast Company* 2013: http://www.fastcodesign.com/3021522/innovation-by-design/mit-invents-a-shapeshifting-display-you-can-reach-through-and-touch.

Gregoire C. 10 things highly intuitive people do differently. *Huffington Post* 2014: http://www.huffingtonpost.com/2014/03/19/the-habits-of-highly-intu_n_4958778.html.

Nakagaki K, Inamura C, Totaro P, et al. Linked-stick: Conveying a physical experience using a shape-shifting stick. *CHI'15 Extended Abstracts 18-23 Apr 2015, Seoul, Republic of Korea*; ACM 978-1-4503-3146: http://tmg-trackr.media.mit.edu/publishedmedia/Papers/577-LinkedStick%20Conveying%20a/Published/PDF.

Creating Sustainable Futures in a World Increasingly Dependent on Technology

Video

"Architecture That Senses and Responds" TED Talk by Carlo Ratti. With his team at SENSEable City Lab, MIT's Carlo Ratti makes cool things by sensing the data we create. He pulls from passive data sets—like the calls we make, the garbage we throw away—to create surprising visualizations of city life. And he and his team create dazzling interactive environments from moving water and flying light, powered by simple gestures caught through sensors. https://www.ted.com/talks/carlo_ratti_architecture_that_senses_and_responds

"No Roads? There's a Drone for That" TED Talk by Andreas Raptopoulos. A billion people in the world lack access to all-season roads. Could the structure of the Internet provide a model for how to reach them? Andreas Raptopoulos of Matternet thinks so. He introduces a new type of transportation system that uses electric autonomous flying machines to deliver medicine, food, goods, and supplies wherever they are needed. http://www.ted.com/talks/andreas_raptopoulos_no_roads_there_s_a_drone_for_that

"What Happened When I Open-Sourced My Brain Cancer" TED Talk by Salvatore Iaconesi. When artist Salvatore Iaconesi was diagnosed with brain cancer, he refused to be a passive patient—which, he points out, means "one who waits." So he hacked his brain scans, posted them online, and invited a global community to pitch in on a "cure." This sometimes meant medical advice, and it sometimes meant art, music, emotional support—from more than half a million people.
https://www.ted.com/talks/salvatore_iaconesi_what_happened_when_i_open_sourced_my_brain_cancer

Suggested Reading

Reubold T. What does a sustainable future actually look like? *Ensia* 2014: http://ensia.com/voices/what-does-a-sustainable-future-actually-look-like.

Schwartz A. Four concepts for the future that could create a more sustainable world. *Fast Company* 2012: http://www.fastcoexist.com/1680109/four-concepts-for-the-future-that-could-create-a-more-sustainable-world=.

Developing Programs to Engage and Empower Communities to Address Threats to Ecosystems

Video

"Dance vs. PowerPoint, a Modest Proposal" TED Talk by John Bohannon. Use dancers instead of PowerPoint. That's science writer John Bohannon's "modest proposal." In this spellbinding choreographed talk he makes his case by example, aided by dancers from Black Label Movement. TED Talk.
https://www.ted.com/talks/john_bohannon_dance_vs_powerpoint_a_modest_proposal

"Desert Running, a PB&J Sandwich, and the Future of Food" TEDxAustin Talk by Robyn Metcalfe. What connects these topics? A tenacious curiosity to see what you can learn by just jumping in.
https://www.youtube.com/watch?v=aKklEFTeLnc

Suggested Reading

Arctic Perspective Initiative. The Arctic Perspective Initiative (API), a transnational art, science, and culture working group, intends to direct attention to the global cultural and ecological significance of the Polar Regions. API does this through knowledge sharing, learning from and empowering the local citizens of the North through the creation of open and participatory communications, sensing, aggregation, and transmission technologies and strategies: http://www.artscatalyst.org/arctic-perspective-initiative.

Buytaert W, Zulkafli Z, Grainger S. Citizen science in hydrology and water resources: Opportunities for knowledge generation, ecosystem service management, and sustainable development. *Front Earth Sci* 22 October 2014;2(26):1-21: http://journal.frontiersin.org/article/10.3389/feart.2014.00026/abstract.

"Citizen Science" Encyclopedic Entry National Geographic: http://education.nationalgeographic.com/encyclopedia/citizen-science.

Climate Bubbles. Climate Bubbles was a playful, participatory citizen science project in which bubble blowing games enabled people across the city of Manchester to map air flow and the urban climate. The conceptual process for this project was interesting and uniquely was a cross-disciplinary collaboration where Art Public's Alfie Dennen collaborated closely with members of Lancaster University, London Met Office and Futuresonic to envision and implement the project: http://artpublic.org/projects/past/climate-bubbles.

Dedicated. A collection of photographs and illustrations by Gulf Coast participants following the 2010 Deepwater Horizon oil spill. Curated by Brandon Ballengée with Aurore Ballengée, Phillip Henken, Mike Madden and Gillian Wilson: http://brandonballengee.com/dedicated.

Extreme Citizen Science. Extreme Citizen Science is a situated, bottom-up practice that takes into account local needs, practices and culture and works with broad networks of people to design and build new devices and knowledge creation processes that can transform the world: https://www.ucl.ac.uk/excites.

Pidot J. Forbidden data. *Slate* 2015: http://www.slate.com/articles/health_and_science/science/2015/05/wyoming_law_against_data_collection_protecting_ranchers_by_ignoring_the.html.

Public Lab. Public Lab is a community where you can learn how to investigate environmental concerns. Using inexpensive DIY techniques, we seek to change how people see the world in environmental, social, and political terms: http://publiclab.org.

***Scientific American* "Citizen Science."** Listing of current citizen science projects: http://www.scientificamerican.com/citizen-science/?category=energy-and-sustainability.

We Need Us. Explores what we can learn from experiencing data, rather than simply gleaning information from it: http://www.thespace.org/artwork/view/weneedus.

Wrecked on the Inter-tidal Zone. This exploratory project, led by YoHa and The Arts Catalyst, brings together a network of local people with artists and technologists to explore how local "situated" knowledge of the Thames estuary can be combined with artistic investigations and citizen science techniques to explore and respond to a changing contested estuary: http://www.artscatalyst.org/wrecked-intertidal-zone.

Creating Open Data Culture

Suggested Reading

Autogena L, Portway J. Black Shoals Stock Market Planetarium and Most Blue Skies. Black Shoals Stock Market Planetarium is an animated night sky that is also a live representation of the world's stock markets, with each star representing a traded company. Fed by massive streams of live financial information, the stars glimmer and pulse, immediately flickering brighter whenever their stock is traded anywhere in the world: http://www.blackshoals.net/description.html.

Baıly G, Corby T, Mackenzıe J. The Southern Ocean Studies. A project with the British Antarctic Survey that explores how the data it derives from its research in the Southern Ocean could be redeployed in public forms: http://www.reconnoitre.net/bas.

The BRAIN Initiative. Two core principles of the BRAIN initiative are to establish platforms for sharing data; and ready accessibility and effective central maintenance of public, integrated repositories for datasets and data analysis tools, with an emphasis on ready accessibility and effective central maintenance; and validate and disseminate technology. Related to the latter, it is suggested that after validation, mechanisms must be developed to make new tools available to all: http://www.braininitiative.nih.gov/index.htm.

CDP Open Data Portal. Searchable database of open datasets: https://data.cdp.net.

Open Data Institute. The Open Data Institute is catalyzing the evolution of open data culture to create economic, environmental, and social value. It helps unlock supply, generates demand, creates and disseminates knowledge to address local and global issues: http://opendatainstitute.org.

Open Knowledge Foundation. OKF believes open knowledge can empower everyone, enabling people to work together to tackle local and global challenges, understand our world, expose inefficiency and challenge inequality and hold governments and companies to account: https://okfn.org/about.

Open Science Data Cloud. The OSDC enables scientific researchers to easily manage, share, and analyze large datasets: https://www.opensciencedatacloud.org.

Plantwise. Plantwise is a global programme working to increase food security and improve rural livelihoods by reducing crop losses: http://www.plantwise.org.

Project Open Data. Technology evolves rapidly, and it can be challenging for policy and its implementation to evolve at the same pace. Last week, President Obama launched a new Open Data Policy and Executive Order aimed at ensuring that data released by the government will be as accessible and useful as possible. To make sure this tech-focused policy can keep up with the speed of innovation, we created Project Open Data: https://project-open-data.cio.gov.

Roolant L. Data is Culture. *The Space (blog).* Lisa Roolant talks to Gavin Starks and Julie Freeman of the Open Data Institute about unlocking the collective value of data*:* http://www.thespace.org/news/view/odifeature.

Shoothill GaugeMap. Shoothill GaugeMap is an award-winning interactive map with the latest British river level, flow, and groundwater data from Environment Agency and the Scottish Environment Protection Agency. The extensive network of stations across Britain covers all the major rivers as well as many smaller rivers, streams, and brooks. The data displayed on each of the stations on the map is recorded at 15-minute intervals by the Environment Agency and the Scottish Environment Protection Agency: http://www.gaugemap.co.uk.

Vending Machine by Ellie Harrison. A rundown but functional old vending machine stands alone in the Viewpoint Gallery at Plymouth College of Art. Every now and again, without warning, it springs into life—spewing out free packets of crisps for gallery visitors. The machine has been modified. It no longer functions in the conventional way at the whim of snack-hungry students but instead now finds itself in the control of outside forces. . . . Its new nervous system is a networked computer. Hidden out of view and running special software, it continually scans the news on the BBC News RSS feed—commanding the machine only to release snacks when words relating to the recession make the headlines. Whilst seemingly an act of generosity—gifting free food at moments when further doom and gloom is reported—the Vending Machine also hints toward a time in the future when our access to food may literally be determined by wider political or environmental events: http://www.ellieharrison.com/index.php?pagecolor=3&pageId=project-vendingmachine.

Wikidata. Wikidata is a free linked database that can be read and edited by both humans and machines. Wikidata acts as central storage for the structured data of its Wikimedia sister projects, including Wikipedia, Wikivoyage, Wikisource, and others: http://www.wikidata.org/wiki/Wikidata:Main_Page.

YoHa. Database Documentary. Database Documentary is a long-term investigation that seeks to understand how databases change our conduct. The initial research located itself within health databases and was initiated through discussions with Polly Moseley who was working with Liverpool Primary Care Trust trying to initiate a year of art and well-being. Invisible Airs also grew out of database documentary: http://yoha.co.uk/database_documentary.

YoHa. Invisible Airs. Invisible Airs is an art project by YoHa assisted by Stephen Fortune. This work has been examining the changes in conduct bought about through the relational machine. Invisible Airs is an investigation of Power, Governance and Data informed by the expenditure database of Bristol City Council. The project page presents our investigation and catalogues resources that may be of use to others in investigating power, governance, and data. Accessed online August 28, 2015: http://yoha.co.uk/invisible.

Creating a Learning Educational System to Identify Benefits of STEM to STEAM

Video

"Playlist (10 talks) Ken Robinson": 10 TED Talks on Education. Education legend Sir Ken Robinson picked the talks he loves—all full of insight, bright ideas, and, of course, creativity. http://www.ted.com/playlists/124/ken_robinson_10_talks_on_educ

Suggested Reading

Art of Science Learning. The Art of Science Learning is a National Science Foundation–funded initiative that uses the arts to spark creativity in science education and the development of an innovative 21st-century STEM workforce: http://www.artofsciencelearning.org/what-its-about.

Art-Science Prize. Learning through the passionate development of breakthrough art and design ideas informed by concepts at the frontiers of science: http://www.artscienceprize.org/asp.

Boy GA. From STEM to STEAM: Toward a human-centered education. *European Conference on Cognitive Ergonomics;* 26-28 Aug 2013; *Toulouse, France*, http://ntrs.nasa.gov/search.jsp?R=20130011666.

Cernansky R. The Very Model of a Modern Major STEM School. *Smithsonian Magazine* 14 April 2013: http://www.smithsonianmag.com/innovation/the-very-model-of-a-modern-major-stem-school-23163130/?no-ist=&page=2.

Cultural Learning Alliance. STEM + ARTS = STEAM. *Report* June 2014: http://www.culturallearningalliance.org.uk/images/uploads/STEAM_report.pdf.

Daly J. The power of design-based education: A Q&A with TED ebook author Emily Pilloton. *TEDBlogs* 2012: http://blog.ted.com/the-power-of-design-based-education-a-qa-with-ted-ebook-author-emily-pilloton.

Mitchell WJ, Inouye AS, Blumenthal MS, eds. Beyond Productivity: Information, Technology, Innovation, and Creativity. The National Academies Press: Washington, DC, 2003: http://www.nap.edu/catalog/10671.

National Academy of Engineering. Advance personalized learning. Videos and resources available: http://www.engineeringchallenges.org/9127.aspx.

The National Academies of Sciences, Engineering, and Medicine's Board on Higher Education and Workforce. Current projects and resources available: http://sites.nationalacademies.org/pga/bhew.

The National Academies Press. STEM Education Collection. Science, technology, engineering, and mathematics (STEM) are cultural achievements that reflect our humanity, power our economy, and constitute fundamental aspects of our lives that contribute to our nation's competitiveness. This collection considers difference school models of STEM education, highlights research on effective STEM education practices, and identifies conditions that promote and limit school success in STEM. These reports are essential for all educators, policy makers, decision makers in school districts, government agencies, curriculum developers, and parent and education advocacy groups: http://www.nap.edu/collection/39/stem-education.

STEM to STEAM. The STEM to STEAM initiative, championed by the Rhode Island School of Design (RISD), is supported by teachers, researchers, policy makers, students, and businesspeople from RISD and beyond. At the heart of the activity, a team of student research assistants works in the Office of Government Relations to apply their firsthand knowledge of Art + Design education to exploring new avenues for STEM to STEAM: http://stemtosteam.org.

Innovation, Creativity, and Action

Video

"Four Principles for the Open World" TED Talk by Don Tapscott. The recent generations have been bathed in connecting technology from birth, says futurist Don Tapscott, and as a result the world is transforming into one that is far more open and transparent. In this inspiring talk, he lists the four core principles that show how this open world can be a far better place. http://www.ted.com/talks/don_tapscott_four_principles_for_the_open_world_1

"Somethink Completely Different" TEDxRotterdam Event. On June 4, 2010, Somethink Completely Different happened at TEDxRotterdam in the Netherlands. Great thinkers, doers, and artists shared knowledge, ideas, and passion to the benefit of the community. Attendees were inspired by more than 20 speakers, stories and performances about science, technology, design, art, and everything else in life. Straight from the heart. Honest, strong, bright, and different. http://www.ted.com/tedx/events/383 AND http://www.somethinkcompletelydifferent.com

Suggested Reading

Gibbs L. Arts-science collaboration, embodied research methods, and the politics of belonging. *"SiteWorks" and the Shoalhaven Geographies* April 2014;21(2):207-227: http://cgj.sagepub.com/content/21/2/207.abstract.

Lamont T. John Maeda Innovation is born when art meets science. *The Guardian* 13 November 2010: http://www.theguardian.com/technology/2010/nov/14/my-bright-idea-john-maeda.

Le Laboratoire Cambridge. Le Laboratoire Cambridge is a unique art and design center that invites visitors to explore the experiments and wonders of innovators of all kinds discovering at frontiers of science—from leading artists and designers to chefs and master perfumers: http://www.lelaboratoirecambridge.com.

Leong KC. Google reveals its 9 principles of innovation. *Fast Company* 20 November 2013: http://www.fastcompany.com/3021956/how-to-be-a-success-at-everything/googles-nine-principles-of-innovation.

Muller L, Bennet J, Froggett L, Bartlett V. Understanding third space: Evaluating art-science collaboration. *Proceedings of the 21st International Symposium on Electronic Art* 2015: http://isea2015.org/proceeding/submissions/ISEA2015_submission_332.pdf.

Pioneer Works Center for Art and Innovation. Pioneer Works is a center for research and experimentation in contemporary culture. Through a broad range of exhibitions, performances, arts and science residencies, and educational programs, Pioneer Works seeks to transcend traditional disciplinary boundaries, foster community, and provide a space where alternative modes of thought are supported and activated in tangible ways: http://pioneerworks.org/about-2.

Simon HA. The Sciences of the Artificial. MIT Press: Cambridge, MA 1996. Available for purchase: https://mitpress.mit.edu/books/sciences-artificial.

UCLA Art I Sci + Lab. The Art|Sci Center is dedicated to pursuing and promoting the evolving "Third Culture" by facilitating the infinite potential of collaborations between (media) arts and (bio/nano) sciences. The center's affiliation with the California NanoSystems Institute (CNSI) offers access to cutting-edge researchers and their laboratories and a dedicated gallery for exhibitions: http://artsci.ucla.edu/?q=about.

Harnessing the Computers Worldwide to Address Urgent, Global Issues

Video

"Dance vs. PowerPoint, a Modest Proposal" TED Talk by John Bohannon. Use dancers instead of PowerPoint. That's science writer John Bohannon's "modest proposal." In this spellbinding choreographed talk he makes his case by example, aided by dancers from Black Label Movement. TED Talk. https://www.ted.com/talks/john_bohannon_dance_vs_powerpoint_a_modest_proposal

"Four Principles for the Open World" TED Talk by Don Tapscott. The recent generations have been bathed in connecting technology from birth, says futurist Don Tapscott, and as a result the world is transforming into one that is far more open and transparent. In this inspiring talk, he lists the four core principles that show how this open world can be a far better place. http://www.ted.com/talks/don_tapscott_four_principles_for_the_open_world_1

"What Happened When I Open-Sourced My Brain Cancer" TED Talk by Salvatore Iaconesi. When artist Salvatore Iaconesi was diagnosed with brain cancer, he refused to be a passive patient—which, he points out, means "one who waits." So he hacked his brain scans, posted them online, and invited a global community to pitch in on a "cure." This sometimes meant medical advice, and it sometimes meant art, music, emotional support—from more than half a million people. https://www.ted.com/talks/salvatore_iaconesi_what_happened_when_i_open_sourced_my_brain_cancer

Suggested Reading

"Citizen Science" Encyclopedic Entry *National Geographic*: http://education.nationalgeographic.com/encyclopedia/citizen-science.

Extreme Citizen Science. Extreme Citizen Science is a situated, bottom-up practice that takes into account local needs, practices and culture and works with broad networks of people to design and build new devices and knowledge creation processes that can transform the world: https://www.ucl.ac.uk/excites.

Pidot J. Forbidden data. *Slate* 2015: http://www.slate.com/articles/health_and_science/science/2015/05/wyoming_law_against_data_collection_protecting_ranchers_by_ignoring_the.html.

***Scientific American* "Citizen Science."** Listing of current citizen science projects: http://www.scientificamerican.com/citizen-science/?category=energy-and-sustainability.

We Need Us. Explores what we can learn from experiencing data, rather than simply gleaning information from it: http://www.thespace.org/artwork/view/weneedus.

Developing Art-Science Collaborations to Reduce Cross-Cultural Denialism

Video

"The Danger of Science Denial" TED Talk by Michael Specter. Vaccine-autism claims, "Frankenfood" bans, the herbal cure craze: All point to the public's growing fear (and, often, outright denial) of science and reason, says Michael Specter. He warns the trend spells disaster for human progress. http://www.ted.com/talks/michael_specter_the_danger_of_science_denial

"Why We Should Trust Scientists" TED Talk by Naomi Oreskes. Many of the world's biggest problems require asking questions of scientists—but why should we believe what they say? Historian of science Naomi Oreskes thinks deeply about our relationship to belief and draws out three problems with common attitudes toward scientific inquiry—and gives her own reasoning for why we ought to trust science. http://www.ted.com/talks/naomi_oreskes_why_we_should_believe_in_science

Suggested Reading

Achenbach J. Why do many reasonable people doubt science? *National Geographic* 2015: http://ngm.nationalgeographic.com/2015/03/science-doubters/achenbach-text.

American Association for the Advancement of Science. Center for Public Engagement with Science & Technology. Resources that focus on providing scientists and scientific institutions with the resources they need to have meaningful conversations with the public: http://www.aaas.org/pes.

Knobloch-Westerwick S, Johnson BK, Siliver NA, Westerwick A. Science exemplars in the eye of the beholder: How exposure to online science information affects attitudes. *Science Communication* 2015;37(5):575-601: http://scx.sagepub.com/content/37/5/575.full.pdf+html.

Muller L, Bennet J, Froggett L, Bartlett V. Understanding third space: Evaluating art-science collaboration. *Proceedings of the 21st International Symposium on Electronic Art* 2015*:* http://isea2015.org/proceeding/submissions/ISEA2015_submission_332.pdf.

Pew Research Center. Science and innovation reports: http://www.pewresearch.org/topics/science-and-innovation/pages/3.

Varner J. Scientific outreach: Toward effective public engagement with biological science. *BioScience* 2014;64(4):333-340: http://bioscience.oxfordjournals.org/content/64/4/333.full.

Generating Projects That Bring Together the Structure and Systems Between Biology and Art to Create Either Biology or Art

Video

"Architecture That Repairs Itself?" TED Talk by Rachel Armstrong. Venice is sinking. To save it, Rachel Armstrong says we need to outgrow architecture made of inert materials and, well, make architecture that grows itself. She proposes a not-quite-alive material that does its own repairs and sequesters carbon, too. http://www.ted.com/talks/rachel_armstrong_architecture_that_repairs_itself

"How Can Technology Transform the Human Body?" TED Talk by Lucy McRae. TED Fellow Lucy McRae is a body architect—she imagines ways to merge biology and technology in our own bodies. In this visually stunning talk, she shows her work, from clothes that recreate the body's insides for a music video with pop-star Robyn, to a pill that, when swallowed, lets you sweat perfume. http://www.ted.com/talks/lucy_mcrae_how_can_technology_transform_the_human_body

"Metal That Breathes" TED Talk by Doris Kim Sung. Modern buildings with floor-to-ceiling windows give spectacular views, but they require a lot of energy to cool. Doris Kim Sung works with thermo-bimetals, smart materials that act more like human skin, dynamically and responsively, and can shade a room from sun and self-ventilate. http://www.ted.com/talks/doris_kim_sung_metal_that_breathes

"Programming Bacteria to Detect Cancer (and Maybe Treat It)" TED Talk by Tal Danino. Did you know that bacteria can be programmed as though they were computers? Bioengineer and artist Tal Danino is working out how to instruct bacteria to enter cancerous tumors—where it can detect and treat the disease noninvasively. And when Danino isn't tinkering with bacteria's healing potential, he makes artwork with it. http://www.ted.com/talks/tal_danino_we_can_use_bacteria_to_detect_cancer_and_maybe_treat_it

"What Humans Can Learn from Semi-intelligent Slime" TED Talk by Heather Barnett. Inspired by biological design and self-organizing systems, artist Heather Barnett co-creates with *Physarum polycephalum*, a eukaryotic microorganism that lives in cool, moist areas. What can people learn from the semi-intelligent slime mold? http://www.ted.com/talks/heather_barnett_what_humans_can_learn_from_semi_intelligent_slime_1

Suggested Reading

Fortune S. Top 10 art-meets-biology innovations. *Dazed* 2014: http://www.dazeddigital.com/artsandculture/article/17960/1/top-ten-art-meets-biology-innovations.

Nervous System Projects. Nervous System is a generative design studio that works at the intersection of science, art, and technology. We create using a novel process that employs computer simulation to generate designs and digital fabrication to realize products. Drawing inspiration from natural phenomena, we write computer programs based on processes and patterns found in nature and use those programs to create unique and affordable art, jewelry, and housewares: http://n-e-r-v-o-u-s.com/projects/albums/floraform-videos.

Wyss Institute. Wyss Institute's Organs-on-Chips acquired by Museum of Modern Art: http://wyss.harvard.edu/viewpressrelease/193/wyss-institutes-organsonchips-acquired-by-museum-of-modern-art.

Creating Human-Centered Cultures with Human-Centered Technologies

Video

"Human-Centered Design" TED Talk by David Kelley. IDEO's David Kelley says that product design has become much less about the hardware and more about the user experience. He shows video of this new, broader approach, including footage from the Prada store in New York.
http://www.ted.com/talks/david_kelley_on_human_centered_design?language=en

Suggested Reading

Hughes TP. Human-Built World: How to Think About Technology and Culture. University of Chicago Press: Chicago, 2005. Available for purchase: http://www.amazon.com/Human-Built-World-Technology-Culture-science-culture/dp/0226359344.

Jaimes A. Human-centered multimedia: Culture, deployment, and access. *IEEE MultiMedia* 2006: http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=1580429.

Rutirasiri C. Making the business case for human-centered design. *Entrepreneur* 19 November 2014: http://www.entrepreneur.com/article/239948.

All tutorials are available at www.keckfutures.org.

Agenda

THURSDAY, NOVEMBER 12, 2015

7:45 a.m.	**Bus Pickup** Attendees are asked to allow ample time for breakfast at the Beckman Center; no food or drinks are allowed in the auditorium, which is where the welcome and opening remarks take place at 9:30.
8:30 a.m.	Registration (not necessary for individuals who attended Welcome Reception)
8:30 – 9:15 a.m.	**Breakfast** Attendees sit with their seed idea teams during breakfast.
9:15 – 9:30 a.m.	**Welcome and Opening Remarks** C. D. (Dan) Mote, Jr., President, National Academy of Engineering David A. Edwards, Steering Committee Chair

9:30 – 10:30 a.m.	**Keynote Address** *When Artistic Process Leads to Science, Engineering, and Medicine Breakthroughs* David Edwards joined by Mariana Amatullo, Jonathan Fineberg, Don Ingber, Hannes Koch, and Tom Rudin.
10:30 – 10.35 a.m.	**Overview of W. M. Keck Foundation Grant Programs** Maria Pellegrini, Executive Director of Programs, W. M. Keck Foundation
10:35 – 10:45 a.m.	**Sonic Antarctica and Wow and Flutter** Join creators Ken Goldberg and Andrea Polli for discussion about works on display.
10:45 – 11:00 a.m.	Break
11:00 a.m. – 12:15 p.m.	**Build Passion!** Seed Idea Groups: First Meeting
12:15 – 1:15 p.m.	Lunch
1:15 – 1:40 p.m.	**Humanexus** View Humanexus, and join question and answer session with creator Katy Börner.
1:40 – 2:30 p.m.	Ask a Question by Liz Lerman and All Attendees
2:30 – 2:45 p.m.	**Discussion of Partnering and Ask a Question Exercise** Attendees meet in auditorium to share thoughts and observations about collaboration exercise.
2:45 – 3:15 p.m.	**Break/Opportunity to Explore Exhibits: Atlas in Silico by Ruth West** Join creator Ruth West for discussion of work on display.

3:15 – 4:45 p.m.	**Dream!** Seed Idea Groups: Second Meeting
4:45 – 5:00 p.m.	**End-of-Day Debrief** Discussion of one-page seed idea summaries to be submitted by teams tonight, preview of this evening's and tomorrow's schedule and other scheduling announcements.
5:00 p.m.	**Bus Pickup** Attendees brought back to hotel.
6:00 p.m.	Attendees Board Bus to Sandy's Beach Grill for Dinner on Beach
6:30 p.m.	Dinner at Sandy's Beach Grill
8:00 p.m.	Bus pickup (or walk) from Sandy's Beach Grill to Hotel
8:00 – 11:30 p.m.	**Sketch!** Dessert and Time to Work on Seed Challenges. Teams to continue to work on seed ideas. One-page summaries due by end of evening. See "Seed Ideas" tab for detailed information. Light snacks and beverages served.

FRIDAY, NOVEMBER 13, 2015

7:45 a.m.	Bus Pickup
8:15 – 9:45 a.m.	**Pitch!** Breakfast/Seed Idea Pitches. Seed idea groups sit together at assigned tables and provide 1-minute pitches.
9:45 – 10:00 a.m.	**Untitled and Black Turbulence** Join Philip Beesley and Niccolò Casas for brief discussion about works on display.

10:00 – 11:00 a.m.	**Mold!** Seed Idea Groups: Third Meeting
11:00 – 11:30 a.m.	**Break/Creative Engagement** *2015 NAKFI Conference Interactive Roster/Mobile App* Join Carol Lafayette and App developers for brief discussion on the making of the 2015 NAKFI Conference Interactive Roster.
11:30 a.m. – 1:00 p.m.	**Mold!** Seed Idea Groups: Fourth Meeting
1:00 – 2:30 p.m.	Lunch and Food Tracking with Robyn Metcalfe
2:30 – 4:45 p.m.	**Mold!** Seed Idea Groups: Fifth Meeting
3:30 – 3:45 p.m.	**Break/Creative Engagement** *Refraction* Join Dan Goods for brief discussion of work on display.
4:45 p.m.	**End of Day Debrief** Review this evening's and tomorrow's schedule, events, and activities.
5:00 p.m.	**Bus Pickup** Attendees brought back to hotel for working dinner.
6:00 – 10:00 p.m.	**Crystallize!** Working Dinner/Networking Le Whaf demonstration by David Edwards and Marc Bretillot. Seed Idea Groups finalize pitches.

SATURDAY, NOVEMBER 14, 2015

8:15 a.m.	**Bus Pickup** Attendees who are departing for the airport directly from the Beckman Center are asked to bring their luggage to the Beckman Center. Storage space is available.
8:45 – 9:30 a.m.	Breakfast
9:30 – 9:45 a.m.	**Welcome and Framing Discussion** David Edwards welcomes everyone and previews the remainder of conference.
9:45 a.m. – 12:00 p.m.	**Practice!** Seed Idea Groups: Sixth Meeting
12:00 – 1:30 p.m.	**Lunch/Creative Disruption** *oBook by Rachel Field* Join Rachel for demonstration and discussion of oBook. Experience a story with an olfactory accompaniment.
1:30 – 2:40 p.m.	**Reveal!** Seed Idea Group Final Reports (10 minutes per group)
2:40 – 3:00 p.m.	Break
3:00 – 4:30 p.m.	**Reveal!** Seed Idea Group Final Reports (10 minutes per group)
4:45 – 5:00 p.m.	**Closing Remarks/Wrap Up** David Edwards to provide closing remarks.
5:00 p.m.	**Bus Pickup** Attendees brought to Beall Center for Art + Technology for Closing Reception.

5:15 – 7:15 p.m.	**Closing Reception: Beall Center for Art + Technology's Objects of Wonder** Attendees to enjoy closing reception at Beall Center for Art + Technology while viewing Objects of Wonder exhibit.
7:15 p.m.	**Bus Pickup** Attendees brought back to hotel or airport.

Participant List

Mariana Amatullo
Co-Founder and Vice President, Designmatters, ArtCenter College of Design, Pasadena; Design and Innovation Fellow, Weatherhead School of Management, Case Western Reserve University

Scott M. Auerbach
Full Professor/Director
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Postdoctoral Researcher
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Louisiana State University

Bill Barclay
Director of Music
Shakespeare's Globe Theatre

Philip Beesley
Professor
Living Architecture Systems Group in association with University of Waterloo

Jonathan Berger
The Denning Family Provostial Professor in Music
Department of Music
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McGill University

Katy Börner
Victor H. Yngve Professor of Information Science
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Marc Bretillot
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Ian P. Brunswick
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University of Georgia

Asa Calow
Director
MadLab (Manchester Digital Laboratory)

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Donald Danforth Plant Sciences Center

Lisa Chong
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Science Magazine

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Art and Science Laboratory

Barbara J. Culliton
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(tbd) collective

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Maryland Institute College of Art

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Science Writing Scholar
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W. M. Keck Foundation

Michael Pepe
CEO, Acacia Road Ventures

Henry Petroski
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Manuel Toscano
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