Insights
Supporting Artists on STEMM Research Teams: Why and How

The insights in this report are a result of a study undertaken in partnership by the Alliance for the Arts in Research Universities (a2ru) and the Michigan Institute for Clinical & Health Research (MICHR).

Pandemic circumstances dictated that the study did not unfold as planned. Nonetheless, the study yielded new information and provocative questions that we hope the Team Science and Arts Research communities will pursue.

In keeping with our goal of using research to generate good ideas, we look forward to the additional insight that readers like you contribute to it. Please direct feedback to vstanich@umich.edu.

Author:
Veronica Dittman Stanich, a2ru

Contributing Author:
Elizabeth LaPensee, MICHR

On behalf of:
The Alliance for the Arts in Research Universities (a2ru)
a2ru.org

The Michigan Institute for Clinical & Health Research (MICHR)
michr.umich.edu/

Contents

Introduction

In the spring of 2019, the a2ru staff met with George Mashour, then Executive Director of MICHR. MICHR is the Michigan Institute for Clinical & Health Research, the University of Michigan's Clinical and Translational Science Award hub and a2ru's near neighbor on the university's North Campus. The meeting was spurred by his interest in and respect for the arts; indeed, the conversation was defined by his conviction that the arts had important contributions to the clinical and scientific space—perhaps through early arts experiences that still inform the practices of senior scientists, or through collaborative efforts of artists, clinicians, and scientists.

He connected the a2ru research team—comprised then of Research Director Gabriel Harp and me—with Beth LaPensee and Aalap Doshi, who were working at the intersection of team science, design thinking, and human-centered design at MICHR, and over the course of many meetings that summer, we experimented with various permutations of what we might do together. By the fall, we had a plan; we would do a qualitative study tracking research teams that included not only scientists and clinicians but also artists and humanists. We asked: what are the mindsets, approaches, and practices associated with the arts and humanities, and how do they inform the work of interdisciplinary teams—especially those teams whose purpose is scientific or medical? How do widely differing disciplinary backgrounds inform team interaction, resulting in collaboration that is more effective, less effective, or different in some way altogether from collaborative research by a team composed of similar or related STEMM (the popular acronym for Science, Technology, Engineering, Math, and Medicine) disciplines? In short, understanding that different disciplines impart distinctive disciplinary approaches and practices to their members, we wanted to find out what happens when those different approaches and practices come together.

The proposed study would interrogate the space where the two organizations' individual agendas intersected—expansively interdisciplinary team science. Gabe and I had a growing set of insights about arts-integrated collaboration, and Beth and Aalap were offering material support to interdisciplinary teams in the form of team building and facilitation, with a long-term eye toward federal large-scale collaborative funding opportunities in health and science. This was an opportunity to drill into the workings of arts/STEMM teams. In fact, MICHR's interventions—how they facilitated group meetings, the communication and logistic support they offered the groups—became a key part of our research. We realized we were not only looking at the unique dynamics of arts/STEMM research teams but also at the mechanisms that can support them, and a third research question emerged: what sort of support do arts/STEMM research teams need, and what are the most effective mechanisms of that support? *Read the details of MICHR's and a2ru's relevant work in Appendix 1.*

As 2019 ended, a2ru and MICHR entered into an eighteen-month collaborative study period. We received IRB approval for the study and identified two arts/STEMM groups receiving session support from MICHR.

And then COVID-19 happened. One group stopped meeting all together, its members completely consumed with pandemic-related responsibilities and research. The other group forged ahead, but slowly. With university-wide spending restrictions, the funding period for the study was shortened. As a result of these circumstances, our study saw teams only at the earliest conceptualization and development phases of research. We did not have the opportunity to observe how people of

different disciplines interact and participate in the implementation and translation phases of a research process.

However, we do have notes from early-stage brainstorming sessions (hereafter referred to as Research Jams), as well as MICHR email communication, slide presentations, shared documents, reports, surveys, and interviews. We glean insights from these sources using a qualitative research logic. That is, we use this study data to sound a2ru's theories on how interdisciplinary collaboration with artists works. We expect study data to support and reify some aspects of those theories, to enhance and add detail; we also expect study data to contradict some aspects, requiring us to modify our theories. *Read about our approach and methods in Appendix 2.*

Indeed, the a2ru/MICHR study supports much of a2ru's existing understanding of how arts integration works in the university—specifically, theories regarding patterns of best practice for interdisciplinary collaboration, and impacts of arts integration. In particular, MICHR's strategic design and facilitation of brainstorming session augments our understanding of best practices for interdisciplinary collaboration. At the same time, study data disrupt some of our theories about how interdisciplinary groups that include artists work, raising questions and suggesting ideas that don't fit, and thereby change what we thought we knew.

Key takeaways

- Artists bring new perspective, tolerance for ambiguity, synthesis and translation, and a maker practice to the STEMM research space.
- While arts/STEMM teams face many of the same challenges as any interdisciplinary team, two challenges are particularly pronounced: the especially wide divide between STEMM and arts practices and epistemologies, and the perceived hierarchy of knowledge that places science and medicine above the arts.
- Numerous practices help arts/STEMM teams surmount these challenges, including bridging difference, promoting equity, building supportive structures, and creating a positive environment.
- Artists, scientists, and clinicians may or may not have the awareness, skills, or resources to put these practices into play and meet these challenges on their own. Support in the form of education, team facilitation, and thoughtful approaches to collaboration can increase art/STEMM teams' likelihood of success.
- Like most interdisciplinary teams, arts/STEMM teams can also benefit from project management support, funding, and generous timeframes.
- Areas for further exploration include:
    - the original research questions of this study: *How do arts approaches and practices inform the work of STEMM research teams?* The study was curtailed by the COVID-19 pandemic, so exploration of the research questions remains incomplete.
    - the dynamic between disciplinary difference and disciplinary overlap. How does disciplinary difference arouse curiosity and excitement, or create frustration and alienation? How does disciplinary overlap create opportunities for communication and empathy, or diminish the possibility of new perspective?
    - conceiving of scientific and clinical problem spaces in ways that create more entry points for artists and those from other disciplines.
    - imagining entry points into arts research for scientists and clinicians.

Report

MICHR and a2ru set out together to investigate

- the mindsets, approaches, and practices associated with the arts and humanities, and how they inform the work of interdisciplinary teams—especially those teams whose purpose is scientific or medical.
- the ways that widely differing disciplinary backgrounds inform team interaction, resulting in collaboration that is more effective, less effective, or different in some way altogether from collaborative research by a team composed of similar or related STEMM disciplines.
- how to support arts/STEMM groups.

MICHR provided the site for our investigation, insofar as their services for faculty researchers attract a range of interdisciplinary groups. MICHR recognizes that an interdisciplinary team requires a long incubation period before they will be competitive for large federal grants; before they are a functional "team" with a compelling research question, they are a "group" with some shared interests and curiosity. Through their Research Jams, MICHR aims to support potential teams in the earliest stages of their work together: ideation and visioning towards development of a shared research agenda. The insights in this paper are derived from such early-stage work—the Development and Conceptualization phases. As Hall and colleagues articulate in their four-phase model of transdisciplinary research (Hall et al 2012), a problem space is defined and a team assembled in the Development phase; research questions, a conceptual framework, and research design are formulated in the Conceptual phase.

In MICHR's Research Jam service model, a campus researcher who contacts MICHR seeking support for pursuing a complex problem is designated as the Champion. A Champion may already be associated with a loosely formed group of researchers interested in the topic or may have only the seed of a collaborative idea. MICHR works with the Champion to define the problem space, to identify short- and long-term goals for their initiative, and to identify potential participants for a Research Jam. MICHR then works iteratively with the champion to create a Research Jam framework that aligns with their needs and goals. MICHR's design and facilitation of the two- to four-hour Research Jam is strongly informed by design thinking, incorporating many hands-on and interactive elements (LaPensee, Doshi, Salem, Jazdzyk, Steen, Cantrell, and Somers 2021). The broad purpose of a Research Jam is to surface shared research ideas and to build community (LaPensee, Doshi, Salem, Jazdzyk, Steen, Cantrell, and Somers 2021). Research Jams are one service within MICHR's Interdisciplinary Research & Team Science Program; their current and future portfolio of services aim to build and advance collaborative research agendas and elevate team functioning through facilitated experiences, trainings, project management, pilot funding, and research/grant development support.

Our study followed two groups who participated in Research Jams with MICHR. However, within the study timeframe, neither group progressed beyond the early stages of research ideation and relationship building. In one case—an interdisciplinary group assembled to ideate innovations in scoliosis treatment—activity was stalled immediately after the initial Research Jam because of the outbreak of COVID-19 and the Champion's related responsibilities. In the second case—an interdisciplinary group whose members' research addresses various aspects of perception and the senses—the initial brainstorming session has led to intermittent work together, potentially progressing toward collaborative research, education, and scholarly efforts.

We observed both groups in their Research Jam planning meetings and sessions. We interviewed the Champions of both groups, MICHR leadership, and artists and clinicians from a third MICHR interdisciplinary research group studying chronic pain. We also had responses from post-Research Jam participant surveys, and access to MICHR communications, slide presentations, shared documents, and reports. The insights in this study come from analysis of these sources. The study was approved by the Institutional Review Board at the University of Michigan. *See Appendix 2: Research Methodology for more information.*

Context: a2ru research on arts/STEMM collaboration

Most of the insights from this study support or augment a2ru's existing understanding of collaborations that include the arts, especially in the areas of:

1. **the value of artists on STEMM teams** (building on a2ru research into the impacts of arts integration,
2. **particular challenges that arts/STEMM groups face** (building on a2ru and other team science research into interdisciplinary collaboration, and
3. **effective ways to meet the challenges of arts/STEMM collaboration** (building on a2ru and other team science research into interdisciplinary collaboration, and on a2ru's work on patterns of best practice for arts integration.

Some aspects of the study disrupted or raised questions about our understanding of arts-integrated research, see the section below.

Value of artists on STEMM teams

Different perspectives

The team science community understands that complex, multi-dimensional problems call for interdisciplinary research. However, the strength of an interdisciplinary team relies not only on the domain-specific knowledge of its constituent disciplines, but also on their distinctly disciplinary perspectives[1] and approaches, suggesting the value of an expansive team science that seeks participation from a wide range of disciplines. In particular, science and clinical teams stand to benefit from including the arts in all stages of their research processes.

A2RU has substantial insight into the impacts of arts integration in higher education via its two major studies, SPARC and the Arts Engagement project. One high-level impact that both these studies identify is that of new perspective: when the arts are integrated into teaching and research, participants across disciplines encounter the unfamiliar—not just unfamiliar concepts, but unfamiliar ways of thinking about concepts (Harp and Stanich 2019). These encounters are valuable because they compel participants to reconsider what they thought they knew in light of the new, with the possibility that previous knowledge will need to be taken apart and rebuilt. The resultant thinking is often richer and more multi-dimensional.

[1] The idea of a disciplinary perspective is a delicate one as, obviously, members of a discipline do not constitute a monolith. Nonetheless, we suggest that the training and practices associated with a discipline instill a way of regarding and approaching professional practice that has some commonalities. Training in biology includes the concepts of hypothesis, experimentation, and reproducible results, and the practices of observation, measurement, and comparison. Training in choreography includes the concepts of spatial organization, reference or "quoting," and performer variability, and the practices of improvisation, iteration, and variation. As a result of their trainings and experiences, the biologist and the choreographer develop uniquely disciplinary perspectives.

In interviews with group Champions as well as MICHR leadership, enthusiasm about bringing arts perspectives to the clinical/scientific problem space emerged as a recurring theme. The Champions actively worked to include artists at the earliest stages of their group's activities, and all of them spoke about the value of having an arts perspective in their group (see quotations below). In addition, a clinical researcher explicitly spoke about the value of having arts and artists' perspectives in the mix, and an artist noted how interdisciplinary perspectives reveal tacit assumptions (see quotations below). No one involved in the study said anything negative about including arts perspectives.

> "I think that falls in the category of: you don't know what you don't know. So, I feel really strongly that it's only when you bring in totally new perspectives, that they can help connect the dots, where it's really hard for any individual to kind of see that path forward. So I don't have a specific *reason* to invite an architect…I think it's just fun to see what somebody would come up with that I would have never dreamed of." (Champion 1)

> "I think they [musicians and artists] bring different perspectives, different thoughts, different thought processes. So there is something very interesting." (Champion 2)

> "What really draws me to that group [that includes artists] is it often makes me think about humanity in a different way…It sounds cliché but it just does help me in some ways kind of pull back and say, oh, but there's more to being human than always just looking at the data or being focused on clinical aspects of care, and what enthusiasm and excitement does that instill in a researcher to have those kind of conversations and to think in a very different way. And I think that's in part the benefit of having those very divergent perspectives; it often creates new ideas—oh you know, I didn't really ever think about *that* part." (Clinician 14)

> "And that's what's great about interdisciplinary collaboration, *and* in my opinion, when you're immersed in one another's environments, because it's the outsider, the person that notices things that you just take for granted." (Artist 1)

In addition to these spoken acknowledgements of the different perspectives that the arts bring, we observed a phenomenon that seems to be related to the presence of atypical or unfamiliar perspectives. In two small Research Jam discussion groups (Zoom breakout rooms of 3-6 people) where participants were discussing their research, the non-STEMM participants seemed to stimulate clinicians and scientists to engage more actively in discussion. Such animated and engaged discussion among interdisciplinary researchers is a desirable thing in terms of exchanging information, building mutual respect, building enthusiasm, finding areas of common interest, and testing new ideas. In one group comprised of a clinician, a scientist, and an artist, there were long silences and no responses to individual statements until the artist described his research. Then the clinician and scientist asked questions related to details of the artist's work and offered examples of related research; all three became engaged in an animated discussion. They began to note connections among the various research projects, and there were no more pauses in the conversation. In a second discussion group comprised of two clinicians, a scientist, an artist, and a researcher from the School of Business, the arts and business perspectives seemed to spark conversations that ignited similarly, resulting in moments of shared enthusiasm. In a third discussion group comprised only of clinicians and

scientists, these moments of shared excitement were absent; the group fulfilled the task they had been assigned, but there wasn't such animated engagement.

To be sure, these scant observations can't support any claims about how the presence of different disciplinary perspectives in STEMM groups affects the group dynamic. Yet these observations do provide an interesting provocation for exploration: Why might these group discussions have unfolded as they did? Was the presence of an interdisciplinary perspective, and particularly an arts one, an important factor? What other factors were at play? In the first group, the conversation may have sprung to life because the artist included a story that was concrete and personal, whereas the other two had spoken only about their research in the abstract; perhaps this is more conducive to conversation. It may be because the artists in both rooms, and the business researcher in the second, were friendly and dynamic speakers. Or maybe these are examples of optimal arousal, where arts or business research is just unusual enough to arouse the interest of the clinician and scientist, yet is still accessible because it incorporates concepts familiar to a scientist or clinician studying sensory perception. Such a sweet spot—where a person's perspective has the right balance of familiarity and unfamiliarity—might be a characteristic of successful interdisciplinary collaboration broadly, not just where it includes the arts.

In fact, these questions and speculations put a finer point on an original research question posed for this study, *how do different disciplinary backgrounds inform team interaction, resulting in collaboration that is more effective, less effective, or different in some way altogether?* Namely, what is the dynamic between disciplinary difference and disciplinary overlap? Assuming that researchers from all disciplines are present in a group voluntarily, they at least have a shared interest. If there is a sweet spot where the novelty of disciplinary perspective is stimulating but shared interest provides a common ground to keep the conversation going, how do we promote that sweet spot, perhaps through team assembly or facilitation? These questions recur in the section below on shared language.

What artists bring: Uniquely arts contributions

If any interdisciplinary addition to a STEMM research team—be it business or the arts—affords new perspective, what's special about artists? What characteristics or practices do artists bring uniquely?

Valuing artists for their creativity is problematic. As one interviewee, an established artist with long experience in high-profile collaborations with clinicians and scientists, notes, "One of the things that's interesting is a problematic conflation of creativity and art…So there's a lot of people jumping around going, 'But we're creative.' Yes, you are, but you're not an artist. There's a difference between being creative and being an artist. And I think that those differences are actually what makes these collaborations really rich. And if we try and just conflate everything down to some common denominator moosh, there's no point in doing this stuff actually. People need to own what they *do*." This artist articulates two important points: first, that artists don't have a lock on creativity and in fact creativity flourishes across disciplines; second, that we get closer to the valuable aspects of arts integration when we consider what artists *do*. What are practices and approaches associated with the arts? How do the arts train their students to approach the world differently from other disciplines? How do artists and scientists or clinicians approach the materials and challenges of their fields? What is the worldview of an arts discipline and its subdisciplines? If you are trained in the culture of postmodern dance or the culture of organic chemistry, what are you taught to prioritize? What are the typical processes you default to? Bringing the concrete approaches and practices of an

artist to scientific or medical research are, we posit, where arts-integrative research will prove to be valuable.

Arts-specific approaches and practices

It was precisely these approaches and practices that we hoped to observe in interaction, but the onset of the pandemic prevented our study groups from advancing to a team research implementation phase where that might have happened. However, some interviewees articulated qualities of the arts and artists that they found valuable to their medical or scientific research, including tolerance for ambiguity, synthesis and translation, and storytelling as a motivating force (see quotations below).

> "I'm putting together my promotion materials right now and so I was doing a lot of thinking about my teaching portfolio, thinking well, how is it that I formalize and describe how I go about teaching? And that's what really made me connect with how it is I think differently because of my arts background. So in my arts training, we were often given intentionally very vague instructions. So you'd have a very high stakes project, half of your grade, and the most diffuse and ambiguous directions on how to go forward. And I remember that, I'm a pretty linear thinker, so you know it is kind of natural for me to be a researcher too—I'm kind of mathematical and linear—but also creative. And so I remember really having a hard time, thinking, 'My god, the ambiguity! [laughing] This is so hard!' But over time, I really learned to think that way and to be able to tolerate ambiguity and to truly be okay with being creative, and to be a little bit risk-taking. And, I think, to be more comprehensive, to be really really open to different points of view, and I think a lot of that comes from my arts training. And it makes me see a project in two ways. I'll see it in a very linear, research-y way, and then I'll also see it in a much more diffuse, conceptual way." (Clinician 4)

> "I got to the point of my career where I recognized that my activity as a scientist was really becoming more connected to what I did when I was in the liberal arts. Because now, as a senior scientist who's overseeing many different domains of research activity, I'm guiding multidisciplinary discussion on topics, and trying to establish vision and direction—activities that you're not trained to do when you're training scientifically. I discovered, wow, actually I'm back in the liberal arts; this is what I *do* now. I'm really tapping back into critical thinking and creativity: I'm listening, I'm synthesizing, I'm summarizing for the group, I'm trying to project the next steps, I'm highlighting assumptions. I'm translating different disciplines for different people to bring them together around a topic." (MICHR leadership)

> "Most of the research that we [psychologists] do is asking a patient to fill out a questionnaire, for example, and then we sum up the scores and, you know, we look at means and we do regression analyses and it's very quantitatively driven. And that tells a portion of the story, but then there's also that thematic analysis or the qualitative research to say: tell us about your experience with x y or z. It's different from having them circle a number or identify on a scale of 1 to 10 what their rating is of an experience. And so, they [artists on the team] are much more interested in diving deeper into that: tell me the story, and tell me your experience of the story, in just a very different way." (Clinician 14)

These statements indicate some of the arts-based practices and approaches that merit further attention for their benefits to STEMM research teams.

Making

Observations and interviews in this study point to another area that merits further investigation: artistic practice of making things can be understood as research, as a way of investigating a problem space that leads to unique knowledge production, and this can be valuable on a team.

Making is an integral, perhaps defining practice of artists, regardless of whether they work in visual or digital media, music, theatre, or dance. We can understand making—the act of physical creation that directly engages motor and sensory systems, as well as the product that results—as a way of knowing, even though not all artists conceive of their work in this way. Artists who work in higher education settings may be more familiar with thinking about their work as knowledge production because in some institutions with traditional standards for promotion and tenure, they have had to construe their creative practice as research to advance professionally. In fact, many artists and designers define research as "inquiry" or "exploration through making" (Harp 2018).

Indeed, two artists we encountered framed their work as a way of knowing; they develop ideas through making or conceive of their work as a tool for thinking (see quotations below)

> "In visual art, conceptual art terms, it's this idea that we can create art objects that are not necessarily developed for any aesthetic quality, but they're objects for thinking with. So, that object that I made actually does look quite beautiful but its *first* purpose was to be an object to think with…So it's about developing ideas through making." (Artist 1)

> "One big thread is investigative, but there is also ideation. Based on what we know, what do we want to *create?* This is what I can bring; I can design an environment, and use my skill set to design space in a different way." (Artist 7 in conversation with scientists and clinicians about their shared interests)

In some ways, artistic making is not unlike the scientific practice of modeling. Creating a computer generated model or mathematical model or simple diagram is a way of instantiating an idea differently so as to engage with it sensorily: an object for thinking. However, artists' making has motivations and characteristics that differentiate it from scientific modelling. We posit that the following partial list of characteristics of artistic making, gleaned from the literature and our own experiences, are potentially useful in a STEMM research process:

- the thing made is not necessarily intended as a representation of something else
- play—a playful, or exploratory, or enjoyably low-risk, approach (Root-Bernstein, 2019b)
- repetition as adaptation, reproduction, and iteration—as in drafts, rehearsals, variations (Gomez-Marin 2018)
- an emphasis on kinesthetic or body thinking (Root-Bernstein 2019b)—attention to the senses and concrete experience, as opposed to the abstract or purely intellectual. Restated, the process of making sometimes suspends critical thinking, at least temporarily, by suppressing the brain's inhibiting "editor" (Limb and Braun 2008) and entering into a "flow" state

While the groups we followed as part of this study did not advance to a stage of collaborative research where we could explore the role of artistic making in STEMM research, one account of a successful collaborative project between a visual artist and research scientist indicates that it is precisely these characteristics of artistic making that are potentially generative for STEMM research (Ranganathan and Aiden 2021).

Arts/STEMM challenges

In a2ru's previous research, we had identified a number of challenges facing arts-integrated teams, as well as ways that such teams move forward through challenges (Stanich and Harp 2018). This study provided new examples of both challenges and ways forward.

Arts/STEMM teams face at least two particular challenges, beyond those with which every interdisciplinary team must contend. First, the gulf between STEMM and arts practices and epistemologies is especially wide, and second, in much of academia, there is a perceived hierarchy of knowledge that places science and medicine above the arts. Both challenges—the interdisciplinary chasm and the perception of STEMM superiority—must be addressed if arts-STEMM teams are to flourish.

1. Epistemologies, languages, and practices can differ so greatly across disciplines that communication becomes difficult. If in a team effort involving biomedical, social, and behavioral sciences, divergent worldviews can lead to protracted phases of conceptual disagreement (Eigenbrode et al 2007), how much are the difficulties compounded when a team includes disciplines that are distant from each other, as the arts are from science and medicine at many universities? This is sometimes referred to as a broad or wide interdisciplinarity, where there is little or no compatibility of methods, paradigms, or epistemologies (Klein 2010). In interdisciplinary collaborations that include the arts, bridging those differences presents a substantial challenge (Stanich and Harp 2018, 12-14).
2. The sizable discrepancies between 2020 federal funding for the National Science Foundation ($8.3 billion) and the National Endowment for the Arts ($162 million), the parallel gap between funding available for STEMM faculty researchers and arts faculty researchers, and the steady decrease in K-12 arts education opportunities are just a few indicators that the arts are undervalued and expendable in American culture at large and in increasingly STEMM-focused academia. Furthermore, many medical researchers encounter the arts only as modes of therapy; the concept of artists as researchers is unfamiliar. If artists are included in a scientific or medical research initiative, it is often solely for the purpose of presenting or communicating study results in the final, Translation phase. As a result of these familiar roles, scientists, clinicians, and artists may hold stereotypes about each other, make assumptions about what each other does, or perceive hierarchical relationships among their respective fields (Stanich and Harp 2018, 12-13).

Disciplinary difference

Scientists, clinicians, engineers, and artists bring differing content knowledge, practices, epistemologies, and vocabularies to a group. However, a basic scientist and a clinician likely share some frames of reference that an artist does not. For example, most artists do not rely on statistical analysis to support the veracity of research results, as is usually the case with scientific and clinical

research, and may balk at "veracity" as a measure of their research. Such fundamental differences can lead to conflicting assumptions and stymied communication that impede team efforts; indeed, bridging disciplinary difference is of critical importance.

A disciplinary divide was evident in the group engaged in work on sensory perception. The sensory perception Champion, a neuroscientist, created the group because of his hunch that an interdisciplinary approach was most likely to yield innovative advances. After gauging interest in the area, he brought together eighteen faculty researchers to form a core group that would catalyze sensory perception efforts across campus. These faculty members self-identified as working in or interested in some aspect of perception and the senses, and held appointments in engineering, science, and arts departments as well as in the school of medicine. The sensory perception Champion sought support from MICHR to explore possibilities for defining and advancing a sensory perception research agenda. Recognizing the need for cohesion and shared purpose, MICHR staff worked closely with him to design an initial Research Jam for the group that focused on creating a shared vision and identifying and prioritizing key activities to advance their initiative.

The need to bridge difference. At that session, participants were vocal about their curiosity about each other's work, and aware of the need to increase understanding of it if they were to move beyond vague conceptions of what they might do together. When they identified next steps, five of eight suggestions directly addressed bridging disciplinary understanding with activities such as research "speed-dating," formal forums to present their work to each other, and a group field trip with individual members providing unique disciplinary insight. The idea of a forum earned four times as many prioritization votes as any other idea, and two members of the group volunteered to host forums in spring of 2020. (These never happened because of the pandemic.) Post-session surveys also showed continued interest in hosted opportunities to share research. One participant commented, "I think we should have a discussion about what [this work] means, and more importantly, the ways in which we disagree about the meaning, so that we have a clearer goal about what it is that we are trying to accomplish. It is obvious that everyone in the room had a unique view, and in some cases radically different views from each other, of what they want to do. Unless this is addressed head on, we'll continue to talk at cross purposes to each other."

Building bridges for artists into STEMM research. While previous a2ru research identified the significant differences between the practices, backgrounds, and epistemologies of the arts and those in other fields, this study illuminated a specific type of arts/STEMM collaboration: that in which artists are brought into a project that sits squarely in the STEMM space. While the artists may have an affinity for or experience in this problem space, they may not have as much domain knowledge as their STEMM colleagues. Furthermore, default vocabulary and norms may have already been established here, and artists may operate outside of STEMM informal networks. This "outsider" status has the potential to put artists at a disadvantage.

Both the scoliosis and sensory perception groups invited artists into a STEMM problem space, and found that doing this effectively takes extra effort, beyond what would be required in a situation where artists and STEMM practitioners come together on neutral ground. It takes extra effort to identify artists whose work or research agenda coincides with a STEMM purpose, or who would be interested in participating for other reasons. It takes extra effort to provide artists with the additional content knowledge they may need to meaningfully engage in a STEMM initiative. It takes extra effort to keep artists in the loop; the physical spaces on campus where artists work and circulate and the networks to which they belong often have little overlap with STEMM spaces and networks. In

that case, communication must be intentional and sustained so that artists aren't excluded from exchanges that happen on the fly in shared STEMM settings.

Disciplinary hierarchy

In the US, arts advocates lament that arts are the first thing to be cut in K-12 and higher education when budgets are tightened; this reality reflects a common cultural perception in the US that the arts are frivolous and expendable. College students often take an elective dance or painting class for an easy A; they expect fluffy, undemanding pursuits where the usual academic rigor is absent. The concept of the arts as a unique way of knowing, with its own methods, epistemologies, and practices, is largely unfamiliar to non-arts students and faculty alike.

In such an atmosphere, researchers in STEMM fields may be disinclined to think of artists as equals, and as potential research partners. More typically, artists are engaged as late-stage spin doctors who can create an engaging and accessible presentation of research findings. Indeed, artistic and theatrical expressions are often successful at communicating scientific or medical concepts to a broad audience in the Translation phase of research. However, if this is the only understanding of artists' potential contribution, it can lead scientists and clinicians to the damaging assumption that an artist's role is purely cosmetic. A professor in the arts sums up this attitude: "I think the typical tension that I've experienced, and I think a lot of my colleagues experience when they collaborate with any other group, is that there are a lot of misapprehensions about what art is and what artists and designers do. The most common misapprehension is that what we do is about decoration and entertainment, and that we're not the people who really deal with the serious ideas; we're just the ones who make serious ideas look good, or we make them entertaining" (Stanich and Harp, 2018, p. 13). Indeed, many arts faculty at research universities recount similar experiences.

At the initial sensory perception Research Jam, it became clear that individual group members held misconceptions about those in fields different from their own. For example, a neuroscientist in the group suggested that they were fortunate to have people in the room with an eye for visual presentation, and he indicated that faculty from Art and Design were a natural choice to lead the creation of a new website. Although the comment was well-intentioned, it betrayed a lack of understanding about artists and designers, and particularly those present at the sensory perception Research Jam. That is, web design represents a particular area of expertise claimed by only a small subset of those who identify as an artist or designer. Furthermore, artists like those in this group, whose work represents a significant body of arts research, might be offended at the idea that they merely have an eye for visual presentation. Indeed, one artist bristled at the comment and pointed out that website design is paid professional work, not something the artist-researchers in the room ought to take on simply because of their affiliation with the arts. She also objected to the misconception that the function of artists and designers is to make things pretty. There are no parallel accounts of artists in the group holding stereotypes of scientists and clinicians, although these are present in a2ru's previous research.

In line with previous a2ru findings that disagreement or misunderstanding about methods and outcomes are a common challenge for arts-integrated teams (Stanich and Harp 2018, 12), there was evidence in this group of a default mode of knowledge production based in STEMM assumptions. In discussion at a later meeting, one engineer noted that a couple years ago he had tried to form an arts-integrative team, but it was "difficult to quantify the results" and therefore their outcomes were "confusing." Without quantification, the work was "too general and had no tangible outcome."

These statements seem to indicate a belief that quantifiable results of a study are the norm and that results that resist quantification are difficult to understand and, even more, substandard and unacceptable. Many arts-based research outcomes are completely separate from quantification or metrics, yet they are nonetheless tangible and valuable. In fact, Haseman proposes that alongside quantitative and qualitative research there is a third research paradigm, performative research, which is characteristically "Expressed in non-numeric data, but in forms of symbolic data other than words in discursive text. These include material forms of practice, of still and moving images, of music and sound, of live action and digital code" (Haseman 2006).

Effective practices for arts-integrated research teams

a2ru's ongoing research tracks effective patterns of practice for arts integration in the university, as reported by faculty, leaders, and students at research universities. (We use the term "pattern" following architect and planner Chris Alexander, who conceived of Patterns as solutions to problems or challenges which occur over and over again in our environment. The solutions are described in such a way that you can use each one many times over, without ever doing it the same way twice.)

The a2ru patterns all come from individuals' reports of what works; sometimes, but not always, there is a theoretical underpinning for these patterns, but actual practice is prioritized here. These patterns point the way toward a set of best practices for arts integration, or, more accurately, good practices for arts integration (if "best" implies one-size-fits-all solutions that will encounter no obstacles of personality or situation).

We use the following four areas to organize these patterns of practice:

1. Bridge difference/Establish common ground
2. Promote equity/Undo hierarchy
3. Build supportive structures
4. Create a positive atmosphere (i.e., foster behaviors and attitudes that support arts integration)

The definitions of these areas are emergent, and some patterns straddle areas.

This study provided us with new best practices in each area, as well as additional examples of practices we had already identified.

The practices we describe here address the challenges of arts integration foregrounded in this study: differences between disciplinary norms and expectations, and assumptions of disciplinary superiority or hierarchy. While these are the particular challenges of an arts/STEMM research team, they are also present in some measure in any interdisciplinary effort; we hope that our findings here are useful in other interdisciplinary contexts.

We note that the ease or difficulty with which these practices are implemented pivots on leadership that understands and supports arts integration. Leaders can—through their decisions about hiring, funding, communication, practice, and policy—make it easy to bridge difference, promote equity, build supportive structures, and create a positive environment. This is true of institutional leadership at the University of Michigan and at MICHR, and of group leadership such as the Champions who work with MICHR.

For example, MICHR leadership clearly sees the value in an arts-integrated approach to STEMM research. As a result, they created a program dedicated to promoting interdisciplinary research with support services that span the earliest stages of group mobilization and research ideation all the way to collaborative grant submissions. In addition, they fully supported our joint a2ru/MICHR study. Both Champions—leaders of their respective groups—saw the potential for an interdisciplinary approach to their research areas, recognized the need for support for this interdisciplinarity, and worked in partnership with MICHR to move their initiatives forward. They went out of their way to include artists, and to make that inclusion generative. When leadership champions the arts, it provides the foundation for seamlessly implementing best practices.

Bridge difference/Establish common ground

The practices in this area bridge disciplinary differences in background, practice, culture, training, language, and epistemology, enabling interdisciplinary collaborators to access each other's worlds. They also build a conceptual shared space—a common ground—that supports their work together.

Witness each other's practice

This is a pattern a2ru had identified in our previous research, suggesting that collaborators should take the time to visit each other's "home turf" to see what they do when they are at work. The act of physically going to an unfamiliar space, such as a studio or lab, and watching and listening to what goes on there is an efficient way to quickly learn about each other's practice and culture. Seeing a collaborator at work *in situ* can help build a shared body of knowledge and mutual respect, and can even lead to methodological breakthroughs.

One artist we interviewed alluded to the power of such a practice in her own experience, "Having worked with people that themselves are often part of team science—STEM-cell researchers, neuroscientists, et cetera—I've had a really deep interest in the conversations that you have, and the shared experiences, and I would say, immersing yourselves in one another's everyday lived experience, which is actually not the way that lots of artists work with scientists. But some do. There are many insights that come from that, that do have potential to change the way both scientists and artists work in ways that they each find enriching…There's many things I understood or observed about [my collaborator's] language, on how he understood the world as a person and a surgeon, by just doing lots of banal stuff with him."

Identify physical practices shared across disciplines

This practice came up in interviews with that same artist and with a clinician in a leadership role at MICHR (see quotations below). For the artist, it seemed to arise directly from immersing herself in her collaborator's practice—an extension of the simple "witnessing" we had encountered before. For the clinician, the idea arose as a hypothetical. For both, the practice comes from an awareness of the physical world, of the senses and of action. What do people *do* and *experience* when they're working that is in fact the same as, or similar to, the actions and experiences of people in a different discipline? Identifying this common ground helps to build understanding across disciplinary difference.

> "I talk in detail about the work with [this surgeon] and the haptics—you know, the sense of touch. Really, my point there, which I think relates to the general conversation that we're having, is that there are shared languages but they're not necessarily verbal. And you don't necessarily understand you have a shared language

> with somebody from another discipline if you don't understand what their everyday experience of living that discipline is…I think there are physical things we do. There are ways we understand the world, so I guess it's obvious, to surgeons, but it's not necessarily obvious if you're not a surgeon that so much of your expertise is about haptic feedback. It's about well, what's the pressure in the vein now? How's this heart feel? It is about observation. And it's very spatial, spatial awareness. A lot of things are about spatial awareness." (Artist 1)

> "The equivalent for us [scientists] is, let's say you sculpt something, and then you stop, and you look, and you're like, this is s***. Or whatever. No, this is not what I was after. And then there's some process that goes on, you know, go get a cup of coffee. Whatever it is, and then you get back. Well, it's the same. I don't want to say it's the same. What I see as the analogy is, we do an experiment, and then we get the data and we say, oh this is s***. Or that that hypothesis was, you know, or what do I do now to try and re-interpret these data and then take the next move, just as the sculptor is taking the next move. So, I guess what I meant was not the technical aspects of the sculpting or the technical aspects of the experiment, but the processes that drive the direction of it." (MICHR leadership)

Bridge content knowledge gap using multiple modalities

Artists invited into an initiative in a STEMM problem space sometimes lack some specific content knowledge, putting them at a disadvantage in a research collaboration. Curating the need-to-know knowledge, and presenting it in a variety of digestible formats, not only creates the common ground needed for collaboration but also is a gesture of hospitality from STEMM folks inviting artists into their world, contributing to a positive environment. Caring for interdisciplinary collaborators in this way, in the particular scenario where some collaborators are on "home turf" and others are "visiting," has potential application beyond the specific arts/STEMM disciplinary configuration. We observed this highly effective pattern of practice in MICHR's work with one of the Champions.

This Champion was interested in assembling a broadly interdisciplinary group to brainstorm pre-surgical and non-surgical options for scoliosis treatment. While scoliosis is generally understood as a medical issue with surgical, orthotics, and physical therapy implications, she was keen to include participants from a range of disciplines, especially the arts, in the group. MICHR staff worked with the Champion to design and facilitate a Research Jam. It was to be the final event in a week-long training for a type of physical therapy for scoliosis, led by a guest practitioner. Research Jam participants included several physical therapists who had participated in the training as well as practitioners from Physical Medicine and Rehabilitation, some of whom attended the guest practitioner's public talk earlier that day. Faculty from Biomedical Engineering, Mechanical Engineering, Rheumatology, and Orthotics and Prosthetics, as well as from Architecture, Music, and Dance also accepted invitations to the Research Jam. The Champion and MICHR staff were keenly aware of how different these individuals' understandings of scoliosis treatment were likely to be.

MICHR staff and the scoliosis Champion did extensive "pre-work" leading up to the Research Jam to ensure that everyone who attended would understand the usual progression of scoliosis diagnosis and treatment as well as the problem space: namely, non-surgical treatment options that are under-researched or have not been considered critically in years. Before the session, the Champion *emailed* participants several times to explain the purpose of the session and how their expertise and interests

might contribute to the conversation. She also worked with MICHR staff to compose a *framing question*—designed to situate participants in the scoliosis problem space and provoke critical and expansive thinking about its potential. The framing question was posted on large signs around the room and on individual table tents. In addition, the scoliosis Champion collaborated with a designer to craft a graphic *journey map* depicting a typical adolescent's experience with scoliosis diagnosis and treatment. These were available on every table at the brainstorming session. Finally, the Champion prepared a *brief presentation* on scoliosis treatment options, using visuals such as a child's brace, to introduce participants to the session.

These mechanisms enabled all attendees' informed participation and, we posit, the confidence to contribute their unique perspectives regardless of how familiar they were with scoliosis. We note that the scoliosis Research Jam was characterized by lively ideation and discussion among all participants.

One concrete measure of the scoliosis brainstorming session's effectiveness is the extent to which participants were interested in continuing to work together in the problem space. MICHR staff typically closes sessions with a call to action, asking participants to articulate next steps that they can accomplish over a short timeframe. Participants in the scoliosis Research Jam suggested and volunteered for a remarkable six next steps, as compared to two comparable groups where participants volunteered for one next step, or none at all. Notably, those comparison groups did not have common ground established ahead of time, with one participant commenting in a follow–up survey, "It would have been helpful to provide more information on the unmet research needs for [this topic] prior to the session for folks who are unfamiliar with the area." There were other differences between the scoliosis group and these comparison groups that might have impacted the willingness to commit to continued work, including virtual or in-person formats, the presence or absence of artists, individual personalities, and shifting facilitation styles.

Promote equity/Undo hierarchy

The practices in this area address territorialism and assumptions of disciplinary superiority, especially as experienced by artists. They help everyone involved to be on equal footing.

Include artists from the beginning

Many arts faculty find themselves entering an interdisciplinary collaboration late in the game, often to create an engaging visual or theatrical product that communicates outcomes of a study whose trajectory has long been determined. Commissioning artwork as a means of communication, for a commensurate fee, is a legitimate working relationship. However, when there is no fee and artists are called "collaborators" in this situation, they sense that their participation is in the service of others' research, that their ideas are not respected or valuable, and that their work is merely "sprinkles on the cake."

Alternatively, inviting artists into a collaborative research effort from the beginning enables them to bring their perspectives and practices to bear on the initial problem space and to contribute meaningfully to all stages of research.

This was the practice of both groups tracked for this study. For those Champions, MICHR and a2ru staff suggested collaborators from a network of visual artists, musicians, choreographers, performers, architects, designers, and those in related fields whose research and interests seemed

compatible with the problem space. By bringing artists into early conceptual phases of research, MICHR staff model a practice that is educational for members of a group who may not have understood that artists *have* research/creative agendas. That is, when engineers, clinicians, and scientists find themselves ideating with musicians, architects, and dancers at a MICHR brainstorming session, the experience is potentially eye-opening. For those who may have only encountered artists in the context of communicating research results to a broader public or as arts therapy practitioners, the interdisciplinary brainstorming session represents an alternative model, one in which artists with congruent interests might be valued collaborative partners throughout the research cycle. The literature on community-engaged research presents strong arguments for such an inclusive model and the way it builds respect, trust, and shared authority and responsibility in research collaborations with partners whose values and ways of knowing differ from conventional academic norms (Ross et al, 2010; Selker and Wilkins, 2017; Wallerstein and Duran, 2010).

Ask artists what they need from a collaboration

As a corollary to the pattern "Include artists from the beginning," this pattern of practice is operative when the collaboration is happening in a STEMM space and artists are invited in. It implies that participation in a research team should benefit artists professionally, advancing their personal research/creative agendas, just as it does for scientific and clinical members of the team.

This practice surfaced in an interview with an artist: "Let's just add another question in there, to make this even more interesting, which is: what does the artist need out of it, for their own work, to make it something they would do?...So what makes it worthwhile, like a genuine collaboration? An interdisciplinary collaboration in my opinion changes both disciplines and is beneficial to both. And I don't think that many of those science teams or PI's…think it through. I think they all think that we just live to create for other people. Which is bonkers. It's like, well, would you like to come and do some science for free? A huge amount of science for free just cuz it's, (spluttering) you, just, no. There's nothing to do with your research. They'd all absolutely say no. They might go and give the occasional talk. They wouldn't work in a collaboration if they got nothing out of it. So one of the things that I intentionally do with teams is, after we've gotten to know each other a little bit, and (I've) done this with the current team, I've set up a Google doc and I've said, 'What do you need out of this? Do you need a paper? If so, where, and when do you need the data for it? You want an exhibition, what do you need? What do you need?' Which is a really different. It's putting the collaborators at the heart of the project, not only the question or the problem. So there's a question and a problem. And all the scientists understand that what they get out of it as scientists is the papers they write by answering the question. And that's not the way it works in the arts. So what I think what needs to happen more is just the addition of that question" (Artist 1).

Facilitate interdisciplinary group sessions using design thinking-based activities

In settings where one discipline—and its practices and expectations—are in the minority, such as the case where artists are included in a research initiative in a STEMM problem space, that minority discipline might be at a disadvantage. Off their "home turf," they might be perceived as lacking the expertise to contribute to the endeavor. They likely bring different expectations of communication, different understanding of how to interact with a group, and different assumptions about how a project moves forward. As such, there is a likelihood that those from the "visiting" discipline will not be able to participate as easily and as fully in a meeting as those from the "home" discipline who are intimately familiar with its unspoken expectations and assumptions.

For effective collaboration, it is important to bring participants together in ways that support equal participation from everyone. Strategies from the design and design thinking fields are well-suited for this purpose; in addition to their capacity to unleash inherent creativity and curiosity, design thinking strategies foster equity of voice in brainstorming sessions (LaPensee and Doshi, 2020). They do this by mobilizing the visual, accommodating diverse participation styles, and distributing responsibility horizontally.

MICHR designed Research Jam session plans for both study groups that employed these concepts and were highly effective at engaging all participants. Most participant feedback on the sessions was positive, with the most common complaint being the need for more time. However, one participant did note, "I felt that the main ideas that emerged were driven by a few outspoken people - many did not participate." This may be a function of the session being run virtually (because of pandemic restrictions); Zoom allows only one speaker at a time, which can mean that more assertive voices prevail. It may also point to the need to refine activities so as to ensure equitable participation and bears further investigation.

Mobilizing the visual. Following design thinking principles, MICHR Research Jams place an intentional emphasis on visual and interactive mechanisms. Participants write their ideas on colorful sticky notes; the sticky notes are then shared, grouped, and reorganized in visual configurations that reflect categories or affinity-based relationships. Session participants place sticky dots to prioritize affinity groups, and attach "trading cards" with their pictures and names to the clusters of sticky notes that represent ideas they are interested in. Open walls display these tangible, visual artifacts, sparking conversations among participants as they actively engage with them.

Visual mechanisms such as these promote equity among participants by lowering the cognitive demands of participation. Visual representations support perceptual inferences, allowing the eye to do part of the work of understanding (Larkin and Simon 1995, 99). Space-based representations are simpler to recognize and keep in memory, and appear to be particularly well-suited for dealing with ideas concerning sequencing, overlap, and inclusion (Tzonis, 2004). This mode for trafficking ideas, with its relatively low cognitive cost, helps make participation equally accessible to STEMM researchers who may be experiencing artist-as-researcher perspectives for the first time as well as to artists who may be processing new scientific or clinical concepts. MICHR staff observe that visual mechanisms seem to invite collaboration, help get people on the same page, and clarify thinking.

Accommodating diverse participation styles. Session activities are designed to appeal to a range of personal styles, using several modalities for participation. There are opportunities to share ideas and opinions orally with the entire group and with smaller break-out groups. Participants who may be reluctant to speak out have ample opportunities to share ideas in the sticky note writing assignments. Participants can actively engage in the organization of sticky notes into affinity groups to whatever degree they wish; some plunge into this activity while others mostly watch, occasionally stepping in to move a sticky note. Likewise, dot voting and attaching personal playing cards are processes that can be as social and verbal or as silent and contemplative as participants choose. By providing this range of options, MICHR staff levels the participatory playing field, giving all participants equal opportunities to be heard.

Horizontal distribution of responsibility. Although faculty Champions are leaders of their broad research effort, group sessions are meant to foster sharing of ideas across all participants. Design thinking-based activities promote a horizontal distribution of responsibility, enabling greater

inclusion and bubbling of local knowledge in the service of a common goal (LaPensee and Doshi 2020). Activities are structured in such a way that ideas are separated from their author (sticky notes leave participants' hands unsigned to circulate) and methods for prioritization capture input from all participants equally (dot voting). Such structures empower everyone to be part of the process and to feel ownership over collective decisions. This is important not only for artists who might otherwise feel like outsiders in the room, but for groups wherein existing hierarchies may make some members think that their input won't be valued.

Build supportive structures

In a2ru's research, scarcity of time, personnel, money, and space are common barriers to arts-integrative efforts. The practices in this area represent formalized measures to address these scarcities. Ideally, they become institutionalized as durable structures.

Provide financial support

This is a recurring theme in a2ru's research: arts-integrated collaborations are regularly under-resourced. Financial support, and seed money in particular, is vital to advancing these collaborations. Many interviewees in a2ru's existing research complain of administrations that give lip service to interdisciplinarity but don't match their words with concrete support; a few interviewees recount how vital the financial support from their institutions has been. The Champions of both groups in the a2ru/MICHR study remark on the need for funding for their innovative efforts, as well as on the importance of the financial support they did receive (see quotations below). In both cases, this funding was seed money, intended to support an idea in its earliest stages.

> "There was a bit of money...to help support the beginning of the program. Actually, I think it was twenty-five hundred dollars. Yeah. Anyway, so that small amount[2] of money really allowed me to be flexible in order to make something like this [guest practitioner visit and brainstorming session] happen too, so being able to use money for this purpose whereas, as I'm sure you're well aware, even somebody who has really good research funding, you have to use the funding for the intent of the grant. So I didn't have any specified, dedicated funding that I could put towards this, and this is where having some undifferentiated money from MICHR, we could use that to the most effective means. And I think that's really important with pilot types of activities" (Champ 1).

> "So [initially] I went to the then Vice President for Research, and I mentioned this [exploring an interdisciplinary problem space], and he said okay. He gave me a sufficient, but not great amount of money, to start creating something" (Champ 2).

Provide administrative and logistic support

Many involved in arts and arts-integrative efforts in the university are perennially stretched too thin. They wear too many hats and often find themselves with responsibilities that exceed their expertise, pulling them away from the work that excited them in the first place. Both Champions expressed their appreciation for the light project management support that MICHR provided them, including scheduling and email communication with their groups. Especially for the Champion and the members of the sensory perception group, lack of time to devote to an interdisciplinary initiative was a persistent problem; project management assistance was essential for their progress.

---

[2] Note this evidence of differing disciplinary economies; $2500 is not a small amount for many arts faculty.

Provide session planning and facilitation for interdisciplinary teams

The skills of designing and facilitating sessions that effectively promote the functioning of a diverse group are seldom taught along with disciplinary knowledge, and where those skills are absent, outside session planning and facilitation can help advance an interdisciplinary project.

MICHR provided that outside expertise to both groups we studied. The Champions of both groups expressed their appreciation for MICHR's service on this front, participation at these sessions was largely enthusiastic, and the great majority of post-session feedback was positive. Participants also provided constructive feedback that helped MICHR to improve their Research Jams for future groups.

Support non-product-oriented collaboration

This practice surfaced in our interview with an artist with long experience in arts/STEMM research. She said of receiving a major art/science grant for her work with a STEM cell researcher, "It was the first time that [they] had funded a project where we had no outcome. So we didn't go with *a project*, we didn't go saying we're going to make this installation. We said, 'We're going to have interesting conversations and something will come out of it.'…We're probably the team that published the most as a result of that scheme, in science. We published a huge amount in the science, and in the arts and created two exhibition installation works. But I think we also really helped to change the conversation around what it means to collaborate. We wrote about the collaborative process as well."

Funding interesting interdisciplinary conversations is rare in the U.S., yet this artist's experience demonstrates that such a process-oriented agenda can have concrete outcomes. MICHR is investing in that process by supporting arts/STEMM groups at the very earliest, conceptual stages of research, when indeed interesting conversations and curiosity about one another's work are at the fore, as they are for the sensory perception group.

Go outside institutional systems when necessary

This practice doesn't neatly fit in any of a2ru's topic areas (Bridge difference, Promote equity, Build supportive structures, Create a positive environment), but it is related to the *lack* of supportive structures. Arts-integrative efforts face a perennial shortage of resources—money, time, space, and personnel. In our previous a2ru research, we found repeated instances of interdisciplinary groups whose efforts to go through approved university channels—to secure space, to coordinate spending across departments, to get permission to use equipment—met only with obstacles and frustration. These groups ultimately wiggled around and beyond university systems to creatively get what they needed to continue their work.

The scoliosis Champion resorted to this practice to keep the project moving forward when university red tape prevented her from securing space on campus in time (she used athletic space in a neighboring community) and when medical center tech support could not help her navigate necessary equipment (a neighbor helped set it up).

Create a positive environment

The practices in this area address the atmosphere for arts-integrative work, the metaphorical air that collaborators breathe. They have to do with attitudes and behaviors. When, for example, university

leadership publicly supports the arts or when collaborators enter the room with an open, respectful approach, they contribute to a positive environment where arts integration can thrive.

Don't get tethered to one way of understanding

A corollary of the foundational practices of open-mindedness and respect for difference, this practice specifically suggests holding loosely to any one way of knowing, and even cultivating a curiosity about other ways of knowing (see quotations below).

> "Part of being multi-disciplinary or creative is not getting too tethered to one mode of doing things, or one mode of seeing things. To be creative, you can't simply have one framework for viewing the world, and then expect to be unconventional or to break out of that. When you're *trained* and you're hardcore and you're doing great in just one mode, it's hard to shift modes. It's hard to place value on things outside: *What's philosophy going to add, or what's interacting with an artist going to add, when I've already got the complete picture here?* I do think it's harder if you've been raised in just one kind of intellectual tradition or discipline. For me, having that broad exposure from the beginning was important." (MICHR leadership)

> "I call it a kind of radical openness that more scientists have than non-scientists realize…people that break ground I think often exhibit an openness to contradictory or novel thinking. So a lot of them will, even if they don't believe it, they'll consider a doctrine that is counter to their own position." (Artist 1)

Disrupting and questioning existing theory: Areas for exploration

Much of what surfaced in our observations and interviews confirmed or added dimension to a2ru's existing understanding of how arts integration works; artists bring fresh perspectives to STEMM groups, disciplinary difference and inequity present challenges, and a range of practices can mitigate those challenges. However, we did encounter phenomena that upended our understanding, causing us to reconsider and ask more questions.

Shared language

Based on a2ru's previous research as well as the team science literature, we expected there to be a language barrier for artists working with scientists and clinicians. However, in small group conversations among artists, scientists, and clinicians in the sensory perception group, we observed no language barrier; the language of science prevailed. The artists present had done "studies" with "results," and they fluently used terms like "sensory inputs," "cognitive processing," and "cross-modal." In short, they already understood their work explicitly in relationship to neuroscience, and were interested in the sensory science side of their arts.

Familiar with, and even comfortable with, the world of sensory science, these artists are in a way bilingual—able to communicate with a scientific community on its own terms. This raises a number of questions about team assembly and functioning:

- The artists in the sensory perception group were comfortable with STEMM concepts and terminology. How would the group be different if it included artists who aren't as comfortable?

- What were the mechanisms that brought these particular artists into the group? What networks or outreach would be needed to reach other artists who don't conceive of their work in scientific terms?
- What extra facilitation would be required to integrate artists who aren't familiar with STEMM concepts and terminology?
- Are artists who "speak STEMM" especially valuable to an interdisciplinary team because they have boundary-crossing expertise?
- Are artists who don't "speak STEMM" especially valuable because they bring a different perspective?
- How would the conversation be different if all members of the group used arts concepts and terminology?

Artist entry points

In the course of this study, we began to wonder whether some STEMM topics are inherently interdisciplinary. At least on the surface, broad topics--with many research entry points that might be meaningful for a range of STEMM practitioners as well as artists and humanists—seem especially conducive to interdisciplinarity. For example, the sensory perception group included, and seemed to readily accommodate the research agendas of, clinicians in neurology, otolaryngology, ophthalmology, visual sciences, anesthesiology, and psychology; basic scientists in chemistry and biology; engineers; business school faculty interested in marketing; architects; musicians; visual artists, and more. All those people have a deep, disciplinary interest in how the senses perceive; the topic is a capacious container for all those inquiries. Similarly, a clinician we interviewed posited that consciousness is an inherently interdisciplinary topic, that anesthesiologists as well as philosophers and poets, for example, are working on and thinking about consciousness.

That same clinician suggested cardiology research as an example of a topic that is not inherently interdisciplinarity: "If you're doing cardiology research, there's no one in philosophy also working on that same problem." At first glance, the distinction holds; a relatively narrow clinical problem space doesn't seem to accommodate so many different disciplinary research agendas. However, there are counterexamples: coincidentally, an artist we interviewed had worked closely with a cardiac surgeon who regularly partnered with artists and considers them important to his work. In addition, the Champion of the scoliosis group said, "Scoliosis was one of the things I thought would really lend itself to an interdisciplinary approach." We reconfigure our model, then: maybe any problem space—be it broad like sensory perception or comparatively specific like cardiology or scoliosis—is or is not conducive to interdisciplinarity based on how expansively individuals conceptualize it.

This more subjective framing has implications not only for the group leader, who may or may not conceive of their topic as interdisciplinary, but for potential group members who may or may not see a connection between their own work and the topic. How might an arts researcher enter into a clinical problem space like cardiac surgery or scoliosis? There is a chance that a clinical topic holds direct relevance for an arts profession. For example, a dance faculty member invited to the scoliosis brainstorming session said that scoliosis research is outside her area of expertise, but she's aware of the prevalence and impact of the condition for dancers. A faculty member from the school of music similarly noted that some of her students have scoliosis. However, this sort of disciplinary intersection seems very slender, and unlikely to generate enough interest from these arts faculty to motivate them to engage in a long-term interdisciplinary research project around scoliosis. There

may be an arts faculty researcher whose interests specifically include scoliosis, but such a person would likely be hard to find.

A more promising arts entry point into scoliosis or cardiac research likely lies one step removed from specific clinical details, with broader concepts and practices that represent common ground for researchers of different disciplines. The artist's account of the cardiac surgeon provides a glimpse of what this might look like: "His research question was how can we change the way we cut away damage in order to enhance repair, and function? And, he did that by, he worked with a ceramicist as well. But as soon as you start thinking about working with people that create three-dimensional forms, they have a very particular understanding that is often embodied, as you might say from performance, but it's an embodied understanding of how those three-dimensional forms are created, how you alter them, how you mold them or cut them to alter them, and what that, what those changes do to them structurally." That is, the interdisciplinary attraction of the work lay not with the specifics of heart valve repair or ceramics, but with the mutually engaging topics of embodied understanding, of creating three-dimensional forms, of molding and cutting and altering, and of structural change. Hypothetically then (since the scoliosis group has not continued after its initial Research Jam), arts entry points to scoliosis might include three-dimensional curves, central structural support, or development that deviates from an expected course.

Maybe there are two types of inherent interdisciplinarity. One hinges on a broad topic, like sensory perception, that invites many disciplinary perspectives. The other requires sussing out shared practices and abstract concepts from the specific details of a topic to find an interdisciplinary common ground. While this discussion has focused on the specific cases in our a2ru/MICHR study, both these conceptions of an interdisciplinary topic or space for exploration could accommodate a role reversal from what has been described here—a situation in which scientists and clinicians find their way into an arts research project via a shared interest in a broad topic, or shared practices and concepts.

Conclusion

Because the pandemic curtailed this study, the important research questions that inspired it—interrogating the dynamics of disciplinary practices and approaches on an arts/STEMM research team—remain largely unanswered. We hope that a2ru or other researchers can pursue this inquiry.

The implications for faculty arts researchers are significant. In many US universities, still, arts faculty remain isolated from the university research enterprise. There is insufficient funding for the arts and, just as importantly, arts research remains below the radar of algorithmic assessment tools and digital indicators used to track faculty activity; in the big, structural, professional ways that matter, faculty arts research doesn't "count." Demonstrating the value of artists on STEMM teams—which have the substantial funding opportunities of the National Science Foundation (NSF) and National Institutes of Health (NIH), and thus the attention of university leadership—is a step towards demonstrating the value of arts research in its own right. The convictions that launched this study, that the arts have important contributions to scientific and clinical spaces, are the tip of an iceberg; the bulk of that iceberg is the importance of the arts across the university and its populations and, even more, throughout our culture.

Appendix 1: a2ru and MICHR

a2ru

A2RU's research insights are the result of its two large scale studies:

1. SPARC (Supporting Practice in the Arts, Research, and Curricula) interviews. These 579 interviews with students, faculty, staff and leadership at 38 research universities covered a range of topics including values, impacts, definitions, and methods. The study was supported by the Andrew W. Mellon Foundation.
2. The Arts Engagement Project. This collaborative study with ArtsEngine, an interdisciplinary initiative at the University of Michigan, surveyed undergraduates about their experiences with the arts. The team collected over 4000 responses, some of which were longitudinal across a student's four years at the university. These responses provide concrete information about the role of the arts in the undergraduate experience.

Three topics of a2ru research are relevant to this a2ru/MICHR study:

1. **Impacts.** Both SPARC and the Arts Engagement Project revealed a broad array of impacts that the arts have in higher education settings. One of the high-level and recurring impacts of arts integration in the university is the new perspectives that result when the arts and other disciplines encounter each other. Read more about Impacts of Arts Integration in Research Universities.
2. **Interdisciplinary collaboration.** In the SPARC interviews, faculty and leadership spoke about the challenges associated with integrating the arts with other disciplines, both at the institutional and the individual level. Common challenges to interdisciplinary work in the university are scarcity of resources, communication or language difficulty, and assumptions and stereotypes about other disciplines. Read more about Interdisciplinary Collaboration.
3. **Best practices for arts integration.** The a2ru research team gleans best practices not only from the SPARC interviews but from continuing dialogue with a2ru partners doing the "boots on the ground" work of integrating the arts into the fabric of the university. Practicable patterns of best practice for arts integration in the university tend to relate to bridging difference, creating equity, putting solid structures in place, and creating a positive environment. Read more about Patterns of Best Practice.

MICHR

The Michigan Institute for Clinical & Health Research (MICHR), the University of Michigan's Clinical and Translational Science Award hub, offers a multitude of services to advance translational research at U-M and beyond. Specific to this study, MICHR offers programming that supports research teams as they pursue large, team-based grants that will provide the needed funding to tackle complex problems. There are often years of advanced planning required to create a competitive large-scale grant submission, and there is a need to create momentum at the earliest stages of research ideation. To address this, MICHR has developed and implemented Research Jams in which interdisciplinary groups, often comprised of biomedical researchers, clinicians, engineers, artists, and architects, among others, can ideate and mobilize around intractable problems. Often, these sessions serve as 'Day 1' for collaborative thinking, and it is common that participants have never met before. Research Jams foster environments in which participants can collectively and deeply explore potential opportunities in the absence of knowledge regarding the expertise and experiences of others in the room. MICHR looks to the fields of design and design thinking, which offer excellent tools for unleashing the inherent creativity and curiosity within researchers, to create their Research Jams.

MICHR promotes four types of Research Jams that are tailored to group needs:

1. Ideation Jam, bringing together new teams to identify complex problems and collaborative solutions
2. Strategy Jam, guiding small, cohered teams in creating research opportunities and pilot projects
3. Visioning Jam, helping identify audiences, value propositions, and key activities
4. Proposal Jam, mobilizing teams to respond to specific funding opportunity announcements

Read more about MICHR's Research Jams.

Read about how design thinking strategies support team science.

Appendix 2: Research Methodology

Following the case study logic of sociologists like David Byrne and Lars Mjøset, we seek to generalize knowledge without universalizing it, continually accounting for the specifics of each case. This type of generalization allows us to make systematic comparisons between the groups we observe, and between our observations and the literature (Byrne 2009, 1-5). Because we develop our analysis of these cases with reference to knowledge already accumulated in this arena, our insights can contribute to that general knowledge (Mjoset 2009, 60).

Observation and interview were our principal methods of data collection. For both groups that MICHR supported with brainstorming sessions and light project management, we attended all team meetings and facilitator planning sessions. The data set includes notes from these meetings and sessions as well as team email communication, slide presentations, shared documents, reports, surveys, and interviews with the Champions of both teams. In addition, we interviewed two clinicians and an artist from a third group that received funding support from MICHR but not brainstorming session support. Notably, this artist has decades of experience working on scientific and clinical teams, and we gained substantial insight from our interviews with her. We also interviewed a member of the MICHR leadership team.

The study was approved by the Institutional Review Board at the University of Michigan.

Our review of literature, addressing interdisciplinary teams in general and arts-integrative teams in particular, identified recurring challenges for such teams as well as best practices for moving through these challenges (especially Campo, Olson, Olson, & Stokols 2020; Cooke & Hilton 2015; Cross 2019; Falcone et al 2019; Stanich & Harp 2019; Styhre & Eriksson 2008; Thompson 2009). We began our analysis looking for instances of those obstacles and best practices present in our cases. In addition, we looked for novel phenomena, ones that we hadn't anticipated but that spoke to the experience of integrating the arts into medical/scientific teams. Of course, unconscious principles of selection influenced our quest (Mjoset 2009, 55); that is, even as we attempted to build data-driven theory, we could not escape our existing theoretical inclinations. Rather than attempting to erase our researcher biases, we chose instead to acknowledge them and, following sociologist J. Clyde Mitchell, understand that our particular cases are significant precisely because we set them against the accumulated experience and knowledge that we as analysts bring to them (Mitchell 1983, 203).

To do this, we annotated the material—a process of making notes on and about the field notes, interview transcripts, and other data items. This iterative process, making notes about notes as we repeatedly went over the material, both confirmed and subtly redefined our understanding of what was going on in this vast field of interrelated data. We also employed a top-down approach (Erickson 2004); starting with the whole and working towards its parts, we identified some broad categories of concepts that recurred throughout the data. This allowed for the generalization and comparison we sought. Finally, we tested our theorizing with regular peer readings of our analysis.

These methods imply that our findings are not comprehensive or definitive; they represent a piece of a larger picture, the additional details of which will be filled in by additional case studies.

Bibliography

Alexander, Christopher, Sara Ishikawa, and Murray Silverstein. 1977. *A Pattern Language: Towns, Buildings, Construction.* New York: Oxford University Press.

Bammer, Gabriele, Michael O'Rourke, Deborah O'Connell, Linda Neuhauser, Gerald Midgley, Julie Thompson Klein, Nicola J. Grigg, et al. 2020. "Expertise in Research Integration and Implementation for Tackling Complex Problems: When Is It Needed, Where Can It Be Found and How Can It Be Strengthened?" *Palgrave Communications* 6 (1): 1–16. https://doi.org/10.1057/s41599-019-0380-0.

Barnett, Heather, and Robert Whittle. 2006. "Drawing the Line: Some Observations on an Art/Science Collaboration." *Leonardo* 39 (5): 458–60. https://doi.org/10.1162/leon.2006.39.5.458.

Barry, Andrew, Georgina Born, and Gisa Weszkalnys. 2008. "Logics of Interdisciplinarity." *Economy and Society* 37 (1): 20–49. https://doi.org/10.1080/03085140701760841.

Berthoin Antal, Ariane, and Anke Strauß. 2013. *Artistic Interventions in Organizations: Finding Evidence of Values Added.* Creative Clash Report. Berlin: WZB.

Boland, Jr., Richard J., and Fred Collopy, eds. 2004. *Managing as Designing.* Stanford University Press.

Born, Georgina, and Andrew Barry. 2010. "Art-Science." *Journal of Cultural Economy* 3 (1): 103–19. https://doi.org/10.1080/17530351003617610.

Campo, Maritza Salazar, Judith Olson, Gary Olson, and Dan Stokols. n.d. "Team Scholarship Acceleration Lab." Team Scholarship Acceleration Lab (TSAL). Accessed May 5, 2020b. https://tsal.uci.edu/.

Chandrasekaran, B., and Janice Glasgow, eds. 1995. *Diagrammatic Reasoning : Cognitive and Computational Perspectives.* Menlo Park, Calif.: AAAI Press. http://hdl.handle.net/2027/mdp.39015038439074.

"Creative Health: The Arts for Health and Wellbeing." 2019. Americans for the Arts. May 15, 2019. https://www.americansforthearts.org/node/101135.

Crossick, Geoffrey. 2020. "From Bridges to Building Sites: Facilitating Interdisciplinarity in the Arts & Humanities." *SHAPE-ID: Shaping Interdisciplinary Practices in Europe.* Accessed May 11, 2021. https://www.shapeid.eu/from-bridges-to-building-sites-facilitating-interdisciplinarity-in-the-arts-humanities/.

Eigenbrode, Sanford D., Michael O'Rourke, J. D. Wulfhorst, David M. Althoff, Caren S. Goldberg, Kaylani Merrill, Wayde Morse, et al. 2007. "Employing Philosophical Dialogue in Collaborative Science." *BioScience* 57 (1): 55–64. https://doi.org/10.1641/B570109.

Eldred, Sheila Mulrooney. 2016. "Art–Science Collaborations: Change of Perspective." *Nature* 537 (7618): 125–26. https://doi.org/10.1038/nj7618-125a.

Feist, Gregory J. 1998. "A Meta-Analysis of Personality in Scientific and Artistic Creativity." *Personality and Social Psychology Review* 2 (4): 290–309. https://doi.org/10.1207/s15327957pspr0204_5.

Fiore, Stephen M., Michael A. Rosen, Kimberly A. Smith-Jentsch, Eduardo Salas, Michael Letsky, and Norman Warner. 2010. "Toward an Understanding of Macrocognition in Teams: Predicting Processes in Complex Collaborative Contexts." *Human Factors* 52 (2): 203–24. https://doi.org/10.1177/0018720810369807.

Fiske, Edward B, ed. 1999. *Champions of Change: The Impact of the Arts on Learning*. Washington, D.C.: Arts Education Partnership.

Fleming, Lee. 2004. "Perfecting Cross-Pollination." *Harvard Business Review*, September 1, 2004. https://hbr.org/2004/09/perfecting-cross-pollination.

Galafassi, Diego, Sacha Kagan, Manjana Milkoreit, María Heras, Chantal Bilodeau, Sadhbh Juarez Bourke, Andrew Merrie, Leonie Guerrero, Guðrún Pétursdóttir, and Joan David Tàbara. 2018. "'Raising the Temperature': The Arts on a Warming Planet." *Current Opinion in Environmental Sustainability* 31 (April): 71–79. https://doi.org/10.1016/j.cosust.2017.12.010.

Gomez-Marin, Alex. 2018. "A Portrait of the Scientist as a Young Artist: Or, What Neuroscience Can Learn from Dance." *SciArt Magazine,* October, 2018. Accessed January 20, 2020. https://www.sciartmagazine.com/a-portrait-of-the-scientist-as-a-young-artist-or-what-neuroscience-can-learn-from-dance.html

Hall, Kara L., Amanda L. Vogel, and Kevin Crowston. 2019. "Comprehensive Collaboration Plans: Practical Considerations Spanning Across Individual Collaborators to Institutional Supports." In *Strategies for Team Science Success: Handbook of Evidence-Based Principles for Cross-Disciplinary Science and Practical Lessons Learned from Health Researchers,* edited by Kara L. Hall, Amanda L. Vogel, and Robert T. Croyle, 587–612. Springer International Publishing. https://doi.org/10.1007/978-3-030-20992-6_45.

Hall, Kara L., Amanda L. Vogel, Brooke A. Stipelman, Daniel Stokols, Glen Morgan, and Sarah Gehlert. 2012. "A Four-Phase Model of Transdisciplinary Team-Based Research: Goals, Team Processes, and Strategies." *Translational Behavioral Medicine* 2 (4): 415–30. https://doi.org/10.1007/s13142-012-0167-y.

Halpern, Megan K. 2012. "Across the Great Divide: Boundaries and Boundary Objects in Art and Science." *Public Understanding of Science* 21 (8): 922–37. https://doi.org/10.1177/0963662510394040.

Halpern, Megan, and Michael O'Rourke. 2020. "Power in Science Communication Collaborations." *Journal of Science Communication* 19 (4): C02. https://doi.org/10.22323/2.19040302.

Harp, Gabriel. 2018. *What Is Research?* Ann Arbor, MI: Alliance for the Arts in Research Universities. https://doi.org/10.3998/mpub.11560291.

Harp, Gabriel and Veronica Stanich. 2019. *New Perspective, Understanding, Awareness: Impacts of Arts Integration and Interdisciplinary Practice.* Ann Arbor, MI: Alliance for the Arts in Research Universities. https://doi.org/10.3998/mpub.11660546.

Haseman, Brad. 2006. "A Manifesto for Performative Research." *Media International Australia* 118 (1): 98–106. https://doi.org/10.1177/1329878X0611800113.

Kirby, Caitlin K., Patricia Jaimes, Amanda R. Lorenz-Reaves, and Julie C. Libarkin. 2019. "Development of a Measure to Evaluate Competence Perceptions of Natural and Social Science." *PLOS ONE* 14 (1): e0209311. https://doi.org/10.1371/journal.pone.0209311.

Kirk-Lawlor, Naomi, and Shorna Allred. 2017. "Group Development and Integration in a Cross-Disciplinary and Intercultural Research Team." *Environmental Management* 59 (4): 665–83. https://doi.org/10.1007/s00267-016-0809-9.

Klein, Julie Thompson. 2010. "A Taxonomy of Interdisciplinarity." In *The Oxford Handbook of Interdisciplinarity*, edited by Robert Frodeman, 15-30. Oxford , New York: Oxford University Press.

Larkin, J.H. and H.A. Simon. (1995) "Why a Diagram is (Sometimes) Worth Ten Thousand Words." In *Diagrammatic Reasoning: Cognitive and cCmputational Perspectives*, edited by B. Chandrasekara and J. Glasgow, 99-107. Menlo Park: AAAI Press.

LaPensee, Elizabeth, and Aalap Doshi. 2020. "Collective Creativity: Strategies for Catalyzing Interdisciplinary Research." *Journal of Science Communication* 19 (04). https://doi.org/10.22323/2.19040305.

LaPensee, Elizabeth, Aalap Doshi, Barbara Salem, Dianne Jazdzyk, Kaylee Steen, Mark Cantrell, and Emily Somers. 2021. "Mobilizing Cross-Disciplinary Teams to Advance Translational Research Using Design Thinking Methods." *Journal of Clinical and Translational Science* 5 (1). Cambridge University Press: e184. doi:10.1017/cts.2021.823.

Leach, James. 2011. "The Self of the Scientist, Material for the Artist: Emergent Distinctions in an Interdisciplinary Collaboration." *Social Analysis* 55 (3): 143–63. https://doi.org/10.3167/sa.2011.550308.

Leimbach, Tania, and Keith Armstrong. 2018. "Creative Partnerships and Cultural Organisations: 'Enabling' and 'Situating' Arts–Science Collaboration and Collective Learning." In *Transdisciplinary Theory, Practice and Education: The Art of Collaborative Research and Collective Learning,* edited by Dena Fam, Linda Neuhauser, and Paul Gibbs, 241–56. Springer International Publishing. https://doi.org/10.1007/978-3-319-93743-4.

———. 2019. "Improving Transdisciplinary Arts-Science Partnerships." *Integration and Implementation Insights*. April 1, 2019. https://i2insights.org/2019/04/02/arts-science-partnerships/.

Lewis, Jenny M., Sandy Ross, and Thomas Holden. 2012. "The How and Why of Academic Collaboration: Disciplinary Differences and Policy Implications." *Higher Education* 64 (5): 693–708. https://doi.org/10.1007/s10734-012-9521-8.

Leydesdorff, Loet, and Inga Ivanova. 2020. "The Measurement of 'Interdisciplinarity' and 'Synergy' in Scientific and Extra-Scientific Collaborations." *Journal of the Association for Information Science and Technology* 72: 387-402. Accessed February 26, 2021. https://doi.org/10.1002/asi.24416.

Limb, Charles J., and Allen R. Braun. 2008. "Neural Substrates of Spontaneous Musical Performance: An FMRI Study of Jazz Improvisation." *PLOS ONE* 3 (2): e1679. https://doi.org/10.1371/journal.pone.0001679.

Malina, R. F., C. Strohecker, and C. LaFayette. 2015. *Steps to an Ecology of Networked Knowledge and Innovation: Enabling New Forms of Collaboration among Sciences, Engineering, Arts, and Design.* Cambridge, Massachusetts: MIT Press. /paper/Steps-to-an-Ecology-of-Networked-Knowledge-and-New-Malina-Strohecker/91f57c485f2c78ee79d50afb5cb5a1f363b48349.

Nurius, Paula S., and Susan P. Kemp. 2019. "Individual-Level Competencies for Team Collaboration with Cross-Disciplinary Researchers and Stakeholders." In *Strategies for Team Science Success: Handbook of Evidence-Based Principles for Cross-Disciplinary Science and Practical Lessons Learned from Health Researchers*, edited by Kara L. Hall, Amanda L. Vogel, and Robert T. Croyle, 171–87. Cham: Springer International Publishing. https://doi.org/10.1007/978-3-030-20992-6_13.

OECD. 2020. "Addressing societal challenges using transdisciplinary research." *OECD Science, Technology and Industry Policy Papers* 88. Paris: OECD Publishing. https://doi.org/10.1787/0ca0ca45-en.

Payton, Fay Cobb, Ashley White, and Tara Mullins. 2017. "STEM Majors, Art Thinkers (STEM + Arts) – Issues of Duality, Rigor and Inclusion." *Journal of STEM Education : Innovations and Research* 18 (3): 39–47.

Pearce, Celia, Sara Diamond, and Mark Beam. 2003. "BRIDGES I: Interdisciplinary Collaboration as Practice." *Leonardo* 36 (2): 123–28. https://doi.org/10.1162/002409403321554189.

Prager, Katrin. "Do We Need Diversity Science?" 2021. *Integration and Implementation Insights.* February 24, 2021. https://i2insights.org/2021/02/25/diversity-science/.

Prophet, Jane. 2011a. "The Artist in the Laboratory: Co-Operating (T)Reasonably." *Artnodes* 11: 5.

———. 2011b. "Model Ideas: From Stem Cell Simulation to Floating Art Work." *Leonardo* 44 (3): 262–63.

———. 2014. "Recognising Patterns By Touch." Accessed January 13, 2020. http://www.janeprophet.com/wp-content/uploads/2015/05/Jane_Prophet_Recognising_Patterns_By-Touch.pdf.

Prophet, Jane and Mark d'Inverno. 2004. "Creative conflict in interdisciplinary collaboration: interpretation, scale and emergence." In *Interaction: systems, theory and practice*, edited by Ernest Edmonds and Ross Gibson, 251-270. Sydney, Australia: Creativity & Cognition Studios Press.

Ranganathan, Gupi, Aiden Lab, and Erez Lieberman Aiden. 2021. "Unfolding the Genome." *a2ru Ground Works.* Accessed December 1, 2021. https://doi.org/10.48807/2021.0086.

Ranwala, Damayanthi, Anthony J. Alberg, Kathleen T. Brady, Jihad S. Obeid, Randal Davis, and Perry V. Halushka. 2019. "Retreats to Stimulate Cross-Disciplinary Translational Research Collaborations: Medical University of South Carolina CTSA Pilot Project Program Initiative." In *Strategies for Team Science Success: Handbook of Evidence-Based Principles for Cross-Disciplinary Science and Practical Lessons Learned from Health Researchers,* edited by Kara L. Hall, Amanda L. Vogel, and Robert T. Croyle, 261–65. Cham: Springer International Publishing. https://doi.org/10.1007/978-3-030-20992-6_20.

Rödder, Simone. 2017. "The Climate of Science-Art and the Art-Science of the Climate: Meeting Points, Boundary Objects and Boundary Work." *Minerva* 55 (1): 93–116. https://doi.org/10.1007/s11024-016-9312-y.

Root-Bernstein, Robert, Lindsay Allen, Leighanna Beach, Ragini Bhadula, Justin Fast, Chelsea Hosey, Benjamin Kremkow, et al. 2008. "Arts Foster Scientific Success: Avocations of Nobel, National Academy, Royal Society, and Sigma Xi Members." *Journal of Psychology of Science & Technology* 1 (2): 51–63. https://doi.org/10.1891/1939-7054.1.2.51.

Root-Bernstein, Robert, Ania Pathak, and Michele Root-Bernstein. 2019a. "A Review of ACD-STEMM Integration: Part 1: A Taxonomy of Integrated Bridges." *Leonardo* 52 (5): 492–93. https://doi.org/10.1162/leon_a_01579.

———. 2019b. "A Review of ACD-STEMM Integration, Part 2: Controlled Studies of Transdisciplinary Tools-for-Thinking Bridges for Arts-Science Pedagogy." *Leonardo* 52 (5): 494–95. https://doi.org/10.1162/leon_a_01580.

———. 2019c. "A Review of ACD-STEMM Integration, Part 3: Controlled Studies of Additional Transdisciplinary Bridges for Arts-Science Pedagogy and General Conclusions." *Leonardo* 52 (5): 496–97. https://doi.org/10.1162/leon_a_01581.

Ross, L.F., A. Loup, R.M. Nelson, J.R. Botkin, R. Kost, G.R. Smith, and S. Gehlert. (2010) "The Challenges of Collaboration for Academic and Community Partners in a Research Partnership: Points to Consider." *Journal of Empirical Research on Human Research Ethics* 5(1): 19-31. doi: 10.1525/jer.2010.5.1.19.

Saratsi, E., T. Acott, E. Allinson, D. Edwards, C. Fremantle, and R. Fish. 2019. "Valuing Arts and Arts Research." VNP22. *Valuing Nature Paper*. https://valuing-nature.net/valuing-arts-and-arts-research.

Scheffer, Marten, Matthijs Baas, and Tone K. Bjordam. 2017. "Teaching Originality? Common Habits behind Creative Production in Science and Arts." *Ecology and Society* 22 (2): 29. https://doi.org/10.5751/ES-09258-220229.

Schnapp, Lynn M., Liela Rotschy, Troy E. Hall, Stephen Crowley, and Michael O'Rourke. 2012. "How to Talk to Strangers: Facilitating Knowledge Sharing within Translational Health Teams with the Toolbox Dialogue Method." *Translational Behavioral Medicine* 2 (4): 469–79. https://doi.org/10.1007/s13142-012-0171-2.

Selker, H.P. and C.H. Wilkins. (2017) "From Community Engagement, to Community-Engaged Research, to Broadly Engaged Team Science." *Journal of Clinical and Translational Science* 1(1), 5-6.

Sonke, Jill, Virginia Pesata, Jenny Baxley Lee, and John Graham-Pole. 2017. "Nurse Perceptions of Artists as Collaborators in Interprofessional Care Teams." *Healthcar*e; Basel 5 (3): 50. http://dx.doi.org.proxy.lib.umich.edu/10.3390/healthcare5030050.

Stanich, Veronica Dittman, and Gabriel Harp. 2018. *Insights: Interdisciplinary Collaboration in the University*. Ann Arbor, MI: The Alliance for the Arts in Research Universities. Accessed December 1, 2021. https://a2ru.org/wp-content/uploads/2021/07/Insights-Summary-Collaboration4_copyright.pdf

Stevens, Michael J., and Michael A. Campion. 1994. "The Knowledge, Skill, and Ability Requirements for Teamwork: Implications for Human Resource Management." *Journal of Management, A Special Issue of The Journal of Management*, 20 (2): 503–30. https://doi.org/10.1016/0149-2063(94)90025-6.

Stevens, Victoria. 2014. "To Think without Thinking: The Implications of Combinatory Play and the Creative Process for Neuroaesthetics." *American Journal of Play* 7 (1): 99–119.

Stokols, Dan, Judith S. Olson, Maritza Salazar and Gary M. Olson. 2019. "Strengthening the Ecosystem for Effective Team Science: A Case Study from University of California, Irvine, USA." *Integration and Implementation Insights*. February 18, 2019. https://i2insights.org/2019/02/19/team-science-ecosystem/.

Taylor-Wesselink, Keisha, and Doireann Wallace. 2021. *Draft System of Preconditions for Successful Arts, Humanities and Social Sciences Integration*. Zenodo. https://doi.org/10.5281/zenodo.4478450.

Tzonis, A. (2004) "Evolving Spatial Intelligence Tools, from Architectural Poetics to Management Methods." In *Managing as Designing,* edited by R.J. Boland and F. Collopy, 67-73. Stanford: Stanford University Press.

Van Gansbeke, Ramona, Lija Groenewoud van Vliet, and Tânia Moreira, eds. 2020. *S+T+ARTS Collaboration Toolkit*. STARTS Ecosystem. Accessed Oct 21, 2020. https://www.starts.eu/media/uploads/starts-toolkit-13july2020.pdf

Wallace, Doireann, Giovanna de Moura Rocha Lima, Carlo Sessa, and Jane Ohlmeyer. 2021. *Maximising Arts, Humanities and Social Sciences Integration in Inter- and Transdisciplinary Research for Effective Responses to Societal Challenges - SHAPE-ID Policy Brief*. Zenodo. https://doi.org/10.5281/zenodo.4442374.

Wallerstein, N. and B. Duran. (2010) "Community-Based Participatory Research Contributions to Intervention Research: The Intersection of Science and Practice to Improve Health Equity." *American Journal of Public Health* 100 (Suppl 1), S40-S46.

Wickson, F., A. L Carew, and A. W. Russell. 2006. "Transdisciplinary Research: Characteristics, Quandaries and Quality." *Futures* 38 (9): 1046–59. https://doi.org/10.1016/j.futures.2006.02.011.

Yajima, Rieko. 2015. "Catalyzing Scientific Innovation with Design Thinking." *Design Management Review* 26 (1): 18–23. https://doi.org/10.1111/drev.10310.