



# Steps to an Ecology of Networked Knowledge and Innovation

Enabling New Forms of Collaboration among Sciences, Engineering, Arts, and Design

Roger F. Malina, Carol Strohecker, and Carol LaFayette  
on behalf of SEAD network contributors

*Cover image: "Map of Science Derived from Clickstream Data" (2009). Maps of science resulting from large-scale clickstream data provide a detailed, contemporary view of scientific activity and correct the under-representation of the social sciences and humanities that is commonly found in citation data. © Johan Bollen. Used with permission. Originally published in Bollen, J., H. Van de Sompel, A. Hagberg, L. Bettencourt, R. Chute, et al. (2009), "Clickstream Data Yields High-Resolution Maps of Science." PLoS ONE 4 (3): e4803. doi: 10.1371/journal.pone.0004803.*

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## INTRODUCTION

Since the early 2000s, successful collaboration among scientists and engineers on the one hand, and artists, designers, and humanities researchers on the other, has been accelerating. This has generated emerging practices that impact work and have potential to mitigate the difficult problems of our times. Innovations emerging from the intersection of the sciences, engineering, arts, and design are transforming our economic, cultural, and learning contexts.

During the past few years, agencies in the United States, including the National Science Foundation (NSF), the National Endowment for the Arts (NEA), and the National Endowment for the Humanities (NEH), have sponsored workshops convening this community. The National Science Foundation Computer and Information Science and Engineering (CISE) Information & Intelligent Systems (IIS) program sponsored three workshops in 2010 and 2011. Bringing together artists and scientists from across the United States, they addressed needs of the burgeoning community of groups and individuals engaged in transdisciplinary practice. The first workshop in this series, “RE/search: Art, Science, and Information Technology: A Joint Meeting of the National Science Foundation and the National Endowment for the Arts” was held in Alexandria, Virginia, in September 2010. The second workshop, “Bridging STEM to STEAM: Developing New Frameworks for Art/Science Pedagogy” was held at the Rhode Island School of Design in January 2011. The third workshop, “Establishing a Network of Excellence for Art + Science + Technology Research: Infrastructural and Intellectual Foundations,” was held in Troy, New York, at Rensselaer Polytechnic University’s Experimental Media and Performing Arts Center (EMPAC) in March 2011. Two outcomes of these initiatives are the Sciences, Engineering, Arts, and Design (SEAD) network and the Virtual eXchange to Support Networks of Creativity and Innovation amongst Science, Engineering, Arts, and Design (XSEAD) portal. Both were funded by NSF Early Concept Grants for Exploratory Research (EAGER) grants.

The XSEAD portal ([xsead.org](http://xsead.org)) delivers a community platform that provides a centralized view of this emergent field. Typical projects include fast dissemination of multimodal research outcomes, extensive databases of prior and current research, an informed record of science-art curricula, support structures for science-art careers, and evidence of societal impact of interdisciplinary integration.

## **Defining Goals**

Two workshops were held in 2011 to form SEAD. The first, held on September 31–October 1, was hosted by collaborative partner and SEAD Co-Principal Investigator Carol Strohecker, Director of the Center for Design Innovation (CDI), a Winston-Salem–based research center of the University of North Carolina system. The workshop brought together a national community of stakeholders to explore models for organizational structure and process and to develop a vision to serve larger sustainability objectives. Stakeholders included academics, researchers, and industry representatives who participated in former NSF-sponsored workshops. Other participants included members of XSEAD, representatives of federal funding agencies, and professionals representing important cultural movements in twenty-first century research and pedagogy, such as those in the “Do-It-Yourself” (DIY) community of “makers.” Also included were students from Winston-Salem State University, a designated Historically Black University, who participated in documentation and evaluation at the close of the second day.

The second workshop was hosted on November 14–15, 2011, by collaborative partner and SEAD Co-Principal Investigator Gunalan Nadarajan, Vice Provost of Research and Graduate Studies at the Maryland Institute College of Art. This workshop, composed of many of the same participants from the CDI event, developed vision, mission, goals, and long- to short-term objectives for the pilot network. Both workshops were facilitated by Steven Wright, Grove Consulting International, who co-coordinated the events and provided graphic recording of proceedings.

## Developing a Community of Ideas

The SEAD network includes professionals and students in the physical, life, and social sciences; mathematics, engineering, and technology; the creative arts in all their forms; designers of all kinds; and researchers across the humanities. An open-access website ([sead.viz.tamu.edu](http://sead.viz.tamu.edu)) serves the community and includes these statements of purpose, focusing on advocacy in the following four areas:

Culture and economic development

Research and creative work

Learning and education

Collaboration and partnerships

SEAD addresses fundamental challenges, including the need to align academic pedagogies with twenty-first-century thinking skills; to promote diversity of perspectives, approaches, and people in the creative economy; and to benchmark best practices that create critical thinkers and leaders for ever-changing cultural and economic arenas. SEAD provides a platform to generate and disseminate public dialogue about the intellectual, cultural, and economic potential of creative intersections of art, science, and technology.

To create crossover linkages among the two separately funded NSF groups SEAD and XSEAD, SEAD members served on the XSEAD Curatorial Board to develop curated sets of high-quality examples of integrative works. Each set builds visual explanations of works representing a perspective on the history and prospects of the field. XSEAD Principal Investigators (PIs) Thanassis Rikakis and Donna Cox coordinate XSEAD portal development. Beginning in 2011, XSEAD members have contributed to several conferences and publications initiated by SEAD.

SEAD's goal is to create a national network to support science, engineering, art, and design collaborations that engage new forms of computational thinking. This network can become a focal point

for innovation, pooling of resources, and cross-pollination to support transformative initiatives that are possible only through combining expertise from diverse knowledge domains. In recent decades vibrant achievements have emerged through the rapid evolution of computer technologies. Materials scientists and electrical engineers have combined their methodologies to bring silicon into circuitry and to develop insights relating natural and fabricated systems (Iwai and Ohmi 2002). Inheriting from predecessors in cybernetics, Seymour Papert has interwoven mathematics with Jean Piaget's developmental psychology into a particular discipline of artificial intelligence, further combining John Dewey's theories of learning to recommend transformations of educational systems (Minsky and Papert 1969; Papert 1988; Papert 1980; Papert 1999). Alan Kay has extended his fascination with Ivan Sutherland's Sketchpad and its implications for computer graphics by incorporating insights from psychological theories (Kay 1993); the work of Karl Jung inspired Sorel Reisman's representational strategies underlying graphical, icon-based displays (Reisman 1994); the work of Jerome Bruner informed Susan Barnes's development of educational software such as Smalltalk and Squeak (Barnes 2007).

As physicists and engineers developed X-ray, telescopic, stroboscopic, holographic, and other imaging techniques, visual artists experimented with the new expressive potentials they enabled (Frankel 2002; Neil 2010). In turn, artists often influenced the development of these technologies, as well as advances in other disciplines such as architecture and computer science (Haase 2000). Visual artists and musicians created computer language and algorithms while pushing technologies for composing and recording in fields of software engineering, artificial intelligence, graphics, and visualization (Wilson 2002; Dabby 2008). An entire ecosystem of academic programs, research conferences, gallery exhibits, museum programs, and municipal events has emerged through such lively inquiries (Brown University 2010).

Nevertheless, researchers and practitioners attempting to work across disciplines of the arts, sciences, and technology often encounter barriers (Grove Consultants International 2010).

Within disciplines, purists may question the depth or validity of cross-disciplinary work. Members of collaborating disciplines may feel undervalued or misunderstood. Institutions such as universities may not have ways to ascertain, evaluate, or acknowledge the merit of individuals' contributions. Members of the public may not have the literacies to appreciate the value and potentials of outcomes. A network organization such as SEAD provides the means to address such barriers to facilitate effective transdisciplinary collaboration.

A focus on sustainable funding and support is reflected in the structure of the organization, namely a distributed model of lead institutions in which cross-institutional working groups self-select theme areas for development. Topics served by a variety of working groups fall in these categories:

1. Research community development (Research and Creative Work: White Papers Working Group; Culture and Economic Development Group)
2. Collaboration and project matchmaking facilitation (Partnerships Group and XSEAD portal partnering)
3. Expertise referrals (XSEAD portal partnering)
4. Large-scale inter-instructional collaborations (Learning and Education Working Group; Culture and Economic Development Group)
5. Forums to share best practices in "Pre-K to gray," or lifelong learning in formal and informal settings (Learning and Education Working Group)
6. Philanthropic opportunities for public and private funding organizations (Partnerships Working Group; Culture and Economic Development Group)

Long-term fiscal sustainability is a critical concern. SEAD considers examples of for-profit, nonprofit, and hybrid support models, including partnerships with federal agencies, private foundations, industry sponsorships, and inter-institutional

collaborations. We are also interested in how innovative economic models such as microfunding, knowledge transfer, and social networking can be harnessed to support network activities.

## **Project Background**

SEAD builds on a rich body of research on the collaborative nature of arts and technology; as part of developing the SEAD White Papers study, we have compiled a bibliography of more than 40 prior reports that address the needs and problems faced by the emerging SEAD community (see Appendix 3). This compendium, going back 50 years, was both encouraging and discouraging; it is clear that many of the opportunities and obstacles now facing the SEAD community were identified and worked on in the past.

Of particular importance to this research perspective was the publication of *Beyond Productivity*, a report produced by the US National Academy of Science in 2003, which was edited by William J. Mitchell, Alan S. Inouye, and Marjory S. Blumenthal on behalf of the Committee on Information Technology and Creativity with support from the US National Research Council. The report argues that, at the beginning of the twenty-first century, information technology is forming a powerful alliance with creative practices in the arts and design to establish the exciting new domain of information technology and creative practices—ITCP. Some of the recommendations made by this report have been implemented; many have not.

Since *Beyond Productivity* came out in 2003, several things have changed that might motivate a new national study in the United States as well as in other countries. At SEAD gatherings since 2011, it is clear that there has been an almost explosive growth of the community over the past 10 years, with increasing interest in industrial innovation and economic growth agendas, the establishment of a wide variety of university programs, and the emerging vitality of maker and hacker communities as well as other civil society actors.

The SEAD White Papers initiative was chaired by Roger Malina and co-chaired by Carol Strohecker, with the assistance of

an international Steering Group and coordination by Carol LaFayette and Amy Ione. Through an open call in June 2012, we asked the community what obstacles and opportunities they encounter and what related actions they would suggest. We received an impressive and generous response: 73 abstracts, 55 full White Papers, and four detailed meta-analyses; these responses contained 260 Suggested Actions on how to better support transdisciplinary engagement, each naming the specific stakeholders who might best implement them. More than 150 individuals were involved, freely contributing their experience and ideas in an open-access mode of knowledge sharing. What was new in 2013 compared to the climate when *Beyond Productivity* was published in 2003 is the increasing size of the SEAD research and creative community, the accelerating effects of the technologies for networked communication and collaboration, the impressive successes of exemplar transdisciplinary work in recent years, and the urgency of many issues in the face of societal, economic, and cultural concerns. There has also been renewed interest in how the arts, design, and humanities can contribute to science, technology, engineering, and mathematics (STEM) educational initiatives, sometimes known as “STEM to STEAM.”

The metaphor we have chosen to adopt, of an ecology of networked knowledge and innovation, seems pertinent to the new situation. The ecology metaphor describes the social organization of researchers and practitioners engaged in the SEAD network. The metaphor also describes the ontology of new knowledge structures that are emerging through SEAD’s highly collaborative methods and results. In conceptualizing information development and sharing as a “network of knowledge” rather than using the more familiar metaphor of a “tree of knowledge,” we strive to emphasize multifarious connections rather than branching structures that may seem more prescribed or brittle. Diverse, flexible, and dynamic connectedness better characterizes this contemporary work and its relationship to our global context. Bollen et al.’s map of science derived from clickstream data (2009), which appears on the cover of this report, represents an ecologically connected network and reminds us of this fundamental shift in concept and action. In contrast to



hierarchically shared information disseminating from a central point, the interaction of multifaceted nodes of activity and expertise reflects values of diversity and rapidity of response and exchange. Bollen's image helps us to visualize a densely interconnected network of individuals crafting and forging their own studies and careers while shaping promising potentials for a dramatically changing world. Envisioning multiple pathways and relational progressions helps us to structure a concept of transdisciplinarity that is nonhierarchical, nonlinear, and nonsequential. A more egalitarian image of the world emerges, with senses of beauty, hope, and the poise to continue evolving.

The SEAD community of practice is not defined through a disciplinary corpus, but rather is outcomes-focused. As a truly networked knowledge community, it overlaps and connects with other communities of practice and evolves over time. This report, correspondingly, is structured around action clusters that transcend disciplines. These clusters frame questions, or processes, that specific stakeholders can use as entry points for consideration of interventions, many of which inevitably would be long-term. Typically the action clusters pertain to the interests of multiple stakeholders, requiring the interplay of public and private actors and organizations. The Suggested Actions that authors identified, in turn, are key to implementing SEAD practices.

As a final Suggested Action, a consensus emerged among the study participants that the time is right to conduct a new formal study, to assess more comprehensively the emerging SEAD areas of research and practice and opportunities these may present for specific contributions to national agendas.

## **Origin of This Report**

Several of the participants in the SEAD initiative decided to prepare a preliminary report based on broad community consultation, to be delivered to NSF as one of the outcomes of the SEAD network grant. Our surmise was that such a preliminary study might identify the timely need for a new formal, national-scale report in the United States, "Beyond Productivity II." As



was true of the original *Beyond Productivity* (Mitchell, Inouye, and Blumenthal 2003), we are concerned with intersections of computing with the humanities, arts, and design—which the original authors dub Information Technology and Creative Practices (ITCP). But we are also concerned more broadly with the mutual benefits derived from a broad spectrum of sciences and mathematics engaging with creative practices and the humanities. We have settled on the SEAD moniker to signify the broad range of disciplines and to characterize homophonically the actions we hope to germinate. The overarching theme becomes collaboration, as transdisciplinary interests and practices continue to grow and as public discourse increasingly acknowledges the complexity of today's global issues and the need for multiple kinds of expertise in addressing them.

Because the SEAD community is active internationally and is heavily socially networked, contributors to the White Papers hail from around the world. We asked the community what obstacles and opportunities they encounter and what related actions they would suggest. Many of the Suggested Actions proposed in the SEAD White Papers are identical or build upon those already presented previously by members of SEAD and related communities of practice. A number of new areas, however, are identified as opportunities potentially served by large communities of research and practice that are larger and/or stronger than at the times of prior reports.

As we began to synthesize our conclusions, it seemed that rather than reiterating specific suggestions already issued by many previous reports, we would structure this document around action clusters that evolved from a critical mass of the White Papers' comments and suggestions. Accordingly, we isolated 11 action clusters, within which we identified 13 Suggested Actions as key processes and concrete steps for practitioners to implement. (In the list below, action cluster topics are capitalized, and the related Suggested Actions are numbered.) Each of these requires in-depth explication and strategies, which appear in the pages that follow.

## **ACTION CLUSTERS AND KEY PROCESSES**

**TRANSLATING:** Problem-driven connections among academic, commercial, and civil societies

1. Project formation and translational value

**CONVENING:** Overcoming transdisciplinary thresholds

2. Conferences, workshops, camps

**ENABLING:** Sustaining balanced SEAD relationships

3. Forming safe, productive environments for hybrid individuals and practices

**INCLUDING:** Spurring innovation through diversity

4. Communities addressing global issues and local solutions

**EMBEDDING:** Public engagement and negotiation

5. Outreach, “citizen science,” dissemination

**SITUATING:** An emerging ecology of creative places

6. “Alt spaces”

**SENSE-MAKING:** Multimodal knowledge and ways of knowing

7. Integrating understandings through the SEAD perspectives

**DOCUMENTING:** Recording and transmitting

8. Capturing, publishing, curating, archiving

**LEARNING:** Tapping into the passion and creativity of lifelong curiosity

9. Sharing blended experiences

## **COLLABORATING:** Methodologies working across disciplines and institutions

- 10. Collaborations between individuals and disciplines
- 11. Partnering across organizational boundaries

## **THRIVING:** SEAD ingredients as essential contributors to healthy communities

- 12. Ethics and values
- 13. Well-being and joyfulness

These action clusters may frame questions that specific stakeholders can use as entry points for longer-term consideration or interventions. Many of the action clusters pertain to the interests of multiple stakeholders, requiring the interplay of public and private actors and organizations.

### **Synthesis Process**

The synthesis process was carried out by the authors of this report at a weekend retreat hosted by The Institute of Applied Creativity at Texas A&M University in March 2013.

As stated, some 260 separate Suggested Actions were identified. Rather than synthesize or prioritize these Suggested Actions it was decided to “cluster” them into groups of related Suggested Actions. Secondly, rather than group them by the stakeholders to whom they are addressed, as was often done in previous studies, it was decided to work within the network metaphor and cluster the actions around key “processes.” These are key processes needed to overcome obstacles to SEAD practice and take advantage of new opportunities. Stakeholders can use these processes to develop road maps and planning. One of the major findings in this report is this “process” orientation within the networked knowledge metaphor we have adopted.

A final contribution to the synthesis process was the four meta-analyses, each of which analyzed sub-groups of White Papers.

The process used for synthesizing was therefore carried out transparently through open-access interim conclusions and sought to provide a broad scheme rather than narrow prioritization; such prioritization could be the object of subsequent studies.

Finally the draft report was circulated and presented at the May 16, 2013, SEAD symposium in Washington, DC. The feedback resulted in a fine-tuning of this report.

## **CHAPTER 1**

### **SEAD WHITE PAPERS METHODOLOGY**

The process for researching and crafting the SEAD White Papers Report was drawn from on the collaborative nature of the SEAD network. This community of advocates is united by a vision of the importance and value of research and creative work spanning and joining the arts and sciences. SEAD proposed the White Papers initiative as a way to build community around perceived challenges and opportunities in broadly transdisciplinary work. The White Papers Working Group became the mechanism for conducting this research on behalf of and in collaboration with the network. Through efforts of the Working Group, we have been able to solicit Suggested Actions, structure them according to similarities of motivation and purpose, and make them relevant to stakeholders.

Working with an internationally renowned advisory board, SEAD Principal Investigator Carol LaFayette and the White Papers Working Group Cochairs Roger Malina and Carol Strohecker wrote and released a call for papers to incorporate the ideas of active professionals, ensure that the proposed outcomes would benefit the diverse SEAD population, and draw both primary experiences and secondary research into the analysis. In addition, they asked authors to provide “Suggested Actions” that indicated how their ideas could better involve stakeholders and inform other SEAD initiatives. The breadth and diversity of the authors and the topics they examine offer a window into the current landscape of collaborative art, science, technology, and design.

#### **The Process**

Originally, abstracts were developed either by one lead person (coordinator) or a group of interested people (a working group) coordinated by a lead person. When participants/authors developed the abstract into a final White Paper, all original participants endorsed it. Both White Papers and abstracts included Suggested Actions that would be considered as part of the

collective body of data. Professionals from the SEAD community were a part of the research and review process to ensure that the proposed outcomes would benefit the SEAD cohort overall. We intentionally viewed the White Papers and abstracts as living documents posted in an open-access website and posted improved versions of the papers as we received them.

## **The Scope of the Works Submitted**

We requested that authors include roadblocks and opportunities for enabling broadly interdisciplinary work. Our goal was not to examine interdisciplinary work in general, but rather what is happening in the SEAD context. In presenting this perspective, we made it clear that SEAD assumed a broad view of the arts to include not just materials-based creativity, but also liberal arts such as the humanities.

Our call for papers specifically stated that we were interested in including an international perspective in the planned meta-analysis of the White Papers, although the scope of specific papers did not need to include international collaboration issues. This resulted in many papers from authors around the world. The demographics provided in Appendix 4 indicate the level of success in getting an international snapshot of the state of SEAD studies. We recognize, however, that our results are dominated by the English-speaking world in a way that does not reflect the community of practice itself. In addition, the low representation from outside North America and Western Europe does not reflect the vitality of work currently going on in Eastern Europe, Asia, Central and South America, and Africa. We were able to achieve a respectable breadth of international inclusion within the timing of the initiative, but even greater cultural diversity could become possible in a follow-on effort with expanded resources and parameters.

## **The Role of Stakeholders**

The call for papers requested proposed actions and specific stakeholder information. We emphasized that Suggested

Actions were intended not for the NSF, the funder of the project. Rather, the authors' focus was to be on the broader landscape of stakeholders and beneficiaries of their SEAD initiatives. These groups might include a variety of agencies, foundations, educational institutions, nonprofits, or other "agents." Similarly, although the White Papers initiative was not an effort to claim that art advances science or vice versa, individual authors did express such points of view. The SEAD network has given voice to these practitioners individually and collectively.

We defined *stakeholders* as consumers of specific products or technologies, government agencies, SEAD students and professionals, and all who have a vested interest in SEAD success. Thus the intention was to extend the analysis beyond academia and include, for example, businesses and municipal economic development councils.

Authors did not need to address all stakeholders. The idea was that each paper's proposed actions would clearly address specific stakeholders, identify barriers and opportunities, and recommend strategies. This flexibility allowed for responses that were relevant outside of academic contexts, as well as those having implications for curriculum development.

## **Typology Comparison**

One of the challenges was developing a typology to encompass the diversity of ideas and perspectives. SEAD identified four primary areas for investigation to serve as framing objectives: culture and economic development; research and creative work; learning and education; and collaboration and partnerships. Earlier reports used a number of frameworks. For example, the 2003 *Beyond Productivity* report, which was seen as a precursor to the SEAD effort, had presented approximately 30 suggested prioritized actions, 12 of which were well articulated. This report divided stakeholders into four fluid categories: industry, funders, community, and academia.

Like the authors of *Beyond Productivity*, we found that practitioners span categories. Some practitioners place themselves within the

community, but many practitioners situate their creative practices within academic or industry contexts. Placement is an issue for research as well, which might occur in an industrial or academic context.

As we began to synthesize our conclusions, it seemed that rather than reiterating specific suggestions already issued by many previous reports, we would structure this document around action clusters receiving a critical mass within the White Papers' comments and suggestions. These clusters may frame questions that specific stakeholders can use in considering possible interventions.

Within the clusters identified, we identified 13 Suggested Actions that encompassed and enlarged our four framing objectives. The Suggested Actions, and the White Paper authors who support them, are expanded upon in chapter 3.

The final White Papers (<http://wp.me/P2oVig-4q>) represent a spectrum of interests in advocating for transdisciplinarity among arts, sciences, and technologies. All authors submitted plans of action and identified stakeholders they perceived as instrumental in carrying out such plans. The individual efforts led to an international scope. One of the important characteristics of this collection is that the papers do not represent a collective aim toward an explicit initiative. Rather, they offer a broad array of views on barriers faced and prospective solutions.

In summary, the collected White Papers and associated meta-analyses began as an effort to take the pulse of the SEAD community as broadly as possible. The ideas they generated provide a fruitful basis for gauging trends and challenges in facilitating the growth of the network and implementing future SEAD initiatives.



## CHAPTER 2

### ACTION CLUSTERS AND SEAD GOALS

The true scope of collaborative SEAD research potential is evident in the action clusters and related Suggested Actions. To further articulate the action clusters discussed here and to demonstrate the vibrancy and innovation that cross-collaboration engenders, we have included examples of work by SEAD members. We are grateful to all contributors.

For a listing of specific Suggested Actions pertinent to each action cluster, see chapter 3.

### **TRANSLATING:** Problem-driven Connections among Academic, Commercial, and Civil Societies

#### **1. Project Formation and Translational Value**

Working across traditional boundaries of organizations, disciplines, and sectors is increasingly recognized as a strategy for innovation. Authors suggest concerted action among engineers, industry members, and philanthropists to identify projects with potential commercial value and to promote collaboration toward realization and distribution of results. Benefits may be social and/or economic. SEAD collaborations leading to product development have included ventures in augmented reality, high-end 3D animation, and wearable technologies. One example is the original creation of two new Chinese fonts, which resulted from a collaboration between a university researcher in the arts and an electronics company.

“E-agriculture” has become a prominent area of application for these tools, benefiting particularly from collaborative development of mobile phone apps that can provide information and communication capabilities out in the field. The general usefulness of mobile communication devices has led to requests for the mobile device industry to develop means for open and free content creation that can be readily exchanged across platforms.

Some authors note a strategy for facilitating transdisciplinary collaboration that considers elements common to multiple disciplines. For example, pattern, rhythm, fractal-like structures, and hierarchies can be found in content related to the sciences, engineering, arts, and design; focusing on these common concepts can facilitate translating to or from different application areas. Similarly, natural structures and cyclic properties are present in many in real-world problems; focusing on these concepts could help in communicating toward development of transdisciplinary teams and education about a broad range of topics.

Authors assert that an authentic inquiry mode of learning demands a fundamental restructuring of the school classroom in terms of its organization, teacher-student ratio, processes, time allotment, activities, resources, and tool use. A reconceptualization of the roles of teacher and student is also needed. New approaches would require design and development of new pedagogical activities and materials for teaching and learning. Teachers would need relevant professional development and empowerment. Evaluations are also needed of both the effectiveness of new teaching-learning strategies and methods for their implementation in the classroom.

Some authors say that encouraging students to explicitly consider the transferability of their knowledge can help leverage skills learned in one domain toward understanding in another. Observation and working with patterns, for example, are two skill sets that are relevant in domains of both art and science and thus worth emphasizing in curriculums and in self-reflection on learning. Making explicit how noted polymaths applied skills and transferred knowledge across domains could also promote students' innovative thinking. Aside from conceptual bridging, careful uses of technologies could facilitate learning across domains. Some say that the potentials of mobile technologies for knowledge dissemination and engagement continue to be largely unrealized. Alicia Gibb's *Light-Up Block Prototype* (fig. 1) is a good example of the potential of 3D printing to promote creative, real-world problem solving, thereby translating SEAD innovation into societal use.

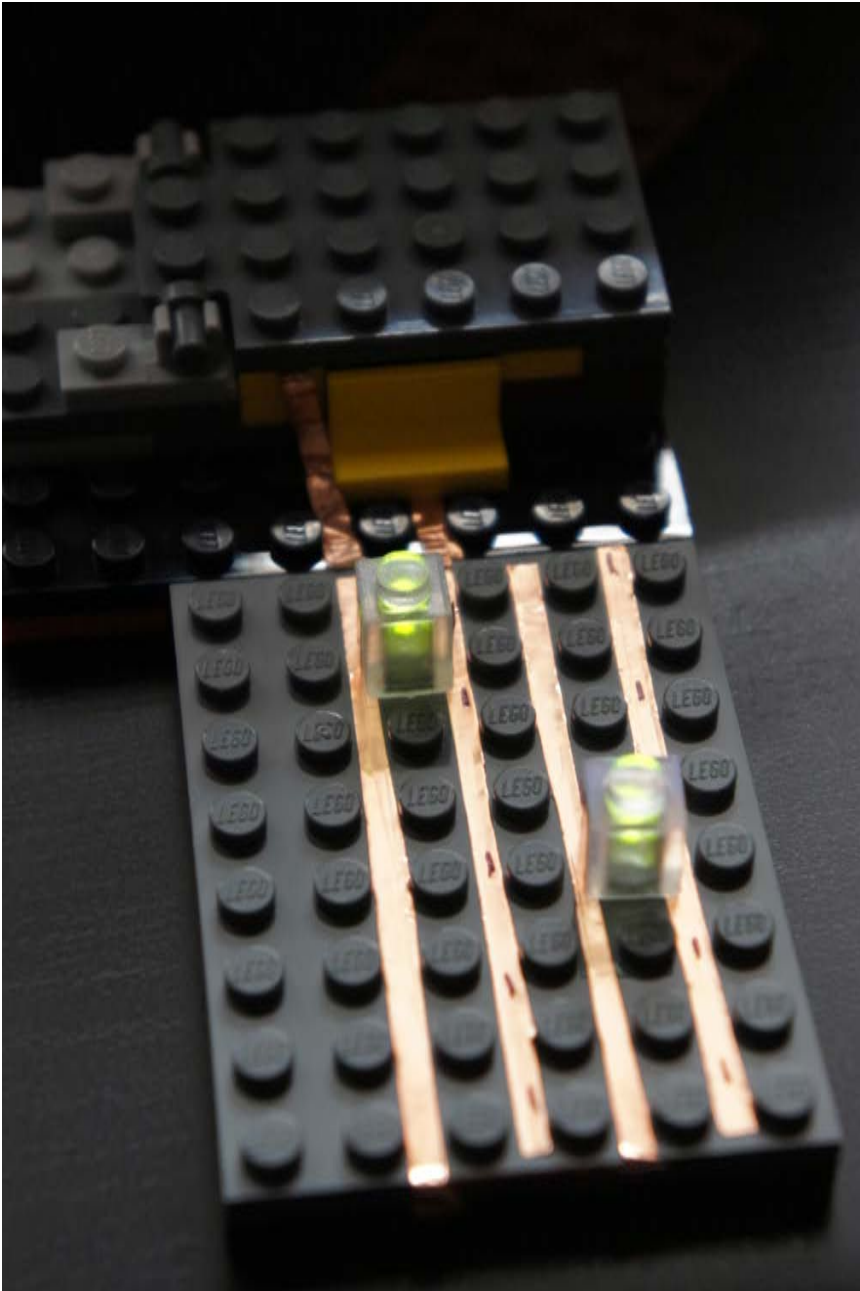



Fig. 1. Light-up block prototype. This hack uses 3D printing to create a block and run power through copper tape to an LED inside. Creator: Alicia Gibb, NYCResistor. 2011. Photo  by SA, Alicia Gibb. <http://aliciagibb.com>.

Several authors address pragmatic concerns that may arise as members of different disciplines attempt to collaborate. The same underlying commonalities that can facilitate translations across disciplines could pose deceptively simplistic views of others' disciplines or of how to work together. Authors repeatedly note the importance for collaborators to learn the content and methods of their partners' domains. The same applies to art critics and other evaluators of results from transdisciplinary collaborations.

Collaborators' commitments to ongoing, cross-cutting learning is necessary to build trust and ensure the quality of results in terms of both depth and breadth, beyond obvious SEAD areas such as scientific illustration and education. Artists could lose interest if the collaborations are framed only in terms of communicating science. Scientists need to understand that visualizations, lab specimens, and models need to be translated as artistic works in order to become appropriate for display in galleries and other artistic contexts.

Authors express the hope that scientists and engineers will concentrate more on inventing innovative technologies that could aid cultural and societal development in emerging countries. Many authors also note the importance of forming partnerships with industry at the outset of a project or as early as possible, in order to include "real-world" perspectives and increase the likelihood of translating results for broader societal benefit. Authors encourage SEAD practitioners to broaden and diversify their own networks, rather than placing the burden of trust-building on a collaboration among strangers. They also recommend that funders underwrite interdisciplinary research in all phases of their decision-making processes. An underlying consideration is the importance of maintaining records of transdisciplinary collaborations and their outcomes.

Many of the White Papers emphasize the need to create collaborations that do not seek to merge disciplines, but rather to create agile and evolving cross-connections among disciplines. Techniques from "translation studies" within the humanities may be of interest: the field of translation studies has evolved beyond

linguistic translation to cross-cultural, cross-media, and cross-discipline translation.

Despite the growing visibility of successful collaborations and translations of SEAD work, many people still need to be convinced of the value of working across disciplines. Some authors suggest that members of scientific communities may more readily accept the premise if presented with rigorous evidence of theoretical or experimental benefits.

Just as in medical research it has been necessary to establish targeted “translational medicine” approaches to transfer research results into societal use, so it is the case for SEAD. Translating SEAD innovation into societal use requires deploying a variety of devices in collaboration; partnering; investing in alternative spaces and accelerator and incubator strategies; multi-outcome funding; and organization. Given the rapidly changing, networked organization and collaboration structures, a specific emphasis on “translational SEAD” seems warranted.

## **CONVENING: Overcoming Transdisciplinary Thresholds**

### **2. Conferences, Workshops, Camps**

This set of actions proposes convening a series of conferences or symposia to pursue dialogue about timely topics, facilitate scouting for collaborative partners, and engage funders in considering the merits and potentials of specific SEAD-related interest areas. Calls for an exchange of ideas on certain topics recur throughout the papers. Among these “hot topics” are STEAM learning, MOOCs (massive open online courses), environmental sciences and ecology, complexity and artworks to explicate it, and how to more fully engage scientists in SEAD initiatives.

Several papers underscore the benefits of connecting artists and scientists with local communities. Authors suggest creation of forums for mixing people from business, academic, and nonprofit organizations. The venues might include public events and large-scale displays that invite participation by community members and require different kinds of skills to realize and engage. Podcasts are another possibility, as are forums that



*Fig. 2. The human vasculature connecting the pancreas and the liver. Using MRI data, the AlloSphere Research group has reconstructed an anatomically correct body used as the basis of an interactive simulator to facilitate virtual experiments in the delivery of chemotherapy to cancerous tumors. Collaborators: JoAnn Kuchera-Morin, UC Santa Barbara AlloSphere Research Facility; Jamey Marth, PhD, Center for Nanomedicine, UC Santa Barbara; and the AlloSphere Research Group. 2014. Photo © Paul Wellman. [www.allosphere.ucsb.edu](http://www.allosphere.ucsb.edu).*

explicitly encourage discussion and networking, such as live webcasts and other web-based forums, and “art-science cafes” for physical gatherings. Suggested exchanges vary in formality, from happenstance interactions to roundtable discussions and organized meetings and seminars. One author poses a game-like “appropriation logic” in which participants—whether scientist, engineer, artist, designer, funder, or other—could propose a project so others could then “rephrase” it to begin an exchange. Not surprisingly, the papers repeatedly emphasize involving potential funders along with members of industry, government, and chambers of commerce, as well as researchers and other collaborators on transdisciplinary projects.



Some authors suggest forming a consortium of universities and art schools in an ambitious, transdisciplinary collaboration to compile art, science, and technology work, and evaluations of such work, during the past 20 years. The results of this scholarly effort would be presented through a visual map providing an overview of SEAD foundations.

Another method for this study could be to convene a broadly representational symposium in which discussion of the works is considered as an art form or “text” in and of itself.

Topics suggested for other conferences and online repositories include the central nervous system as a model for modular architecture communication protocols among complex software systems; form and functionality of the human body to inspire collaborative work such as projects created by JoAnn Kuchera-Morin and the Allosphere Research Group (fig. 2); synthetic characters as a mode for developing artificially intelligent systems; environmental cleanups and other convenings that call attention to underlying patterns or rhythms in the natural world, to then become conceptual bases for creative work; topics more generally in biology and life sciences, the physical sciences, and social sciences; and the ways in which a diverse data visualization community could help to address the problems of big data. Authors also suggest that public receptivity to scientific topics could become a gauge for prioritizing funds for research. The workings of transdisciplinary teams, authors note, also warrant further study.

Another particular suggestion is for multimodal, inquiry-based learning programs to arise out of targeted collaboration among brain scientists and educational researchers. Another appeal is for the creation of focus groups, roundtable discussions, and conferences that include members of the fields of dance, choreography, cognitive science, and neuroscience. Another call is for studies of complexity to be incorporated into high-school curriculums, as well as introductions to the history and philosophy of science.

More generally, authors call for the compilation of a “knowledge bank” of “emergent learning” courses and curriculums focusing on unpredictability rather than best practices, and on constraints rather than outcomes. Currently, blended learning approaches that build upon MOOCs are appearing. These courses and events are contributing to the development of SEAD-related curriculums. Discussions among the participants in these online forums and their extensions into associated “real world” cultures could become a rich source for beginning a practitioner- and designer-generated taxonomy to facilitate studies of the milieu and help promote its advancement. Authors suggest that curriculums should span multiple grade levels and that curriculum development should not be confined to small districts, but draw on global resources. Some authors suggest choosing Arduino, Kinect, and Internet technology platforms rather than textbooks. Others would like to see residency programs in community-based wet labs and hacker spaces treated on a par with university artist-in-residence and scientist-in-residence programs, perhaps even as career requirements.

Authors point out that individuals entering collaborative relationships need to maintain an open-mindedness that allows for ongoing adjustments of preconceptions about partners’ disciplines. Likewise, educating one’s collaborator must be ongoing. Productive transdisciplinary collaboration also requires a supportive infrastructure. Residency programs need to be served by appropriate facilities such as black boxes, workshops, or dedicated lab spaces. Private housing for families would be an important source of support for SEAD experimenters. New academic journals, reduced teaching loads, and grants for nontenured faculty, individuals, and community nonprofit organizations could also encourage transdisciplinary collaborations.

To promote innovation, companies could allow time for employees to participate with members of other organizations in transdisciplinary projects. Formal links among organizations could support meetings and forums on cross-disciplinary communication, toward development of a common language



leading to lasting, productive relationships. A common language based on pattern and rhythm, for example, could connect seemingly unrelated viewpoints and yield transformational insights or perceptual shifts in SEAD areas. Data visualization is increasingly important, yet current methods for working with data are diffuse and do not benefit sufficiently from cross-disciplinary knowledge exchange. Platforms such as conferences, workshops, and online open repositories for sharing visual strategies, algorithms, and other methods would be helpful in bringing forward this increasingly needed vernacular.

We have called out a specific “Convening” action cluster because the nature of the SEAD community of practice requires new approaches. We surveyed SEAD network contributors for the conferences they regularly attended and found a heterogeneous list of 67 different conferences, ranging from those focused in science, engineering, mathematics, education, arts, and humanities as well as a few interdisciplinary venues such as the Society for Literature, Science and the Arts and a growing number of visualization conferences internationally. The workshops convened by the NSF, NEA, and NEH leading up to this White Papers study gathered professionals who had never met even though they had overlapping research and teaching practices. It will be the nature of SEAD practice that it will not consolidate into typical disciplinary practice methodologies, with dedicated conferences, but rather requires an evolving and reactive landscape of convenings in a variety of forms, some within existing conference venues, others in ad hoc formats.

## **ENABLING: Sustaining Balanced SEAD Relationships**

### **3. Forming Safe, Productive Environments for Hybrid Individuals and Practices**

A recurring issue in many of our White Papers is the difficulties and obstacles often faced in SEAD practice because of “asymmetries”—the differing personal and institutional environments faced by collaborators from different disciplines. These issues were also raised in *Beyond Productivity* (Mitchell, Inouye, and Blumenthal 2003); if anything, the situation has



Fig. 3. Scalable City. An interactive virtual world where an ersatz city is created through the interactions of users, data, and algorithms. Developer: Sheldon Brown, Director of the Arthur C. Clarke Center for Human Imagination, UC San Diego. 2010. Photo © Sheldon Brown. [scalablecity.com](http://scalablecity.com).

become more complex. These issues are raised in a number of the other action clusters that we have identified; for instance the Situating action cluster is concerned directly with the issue of designing workspace environments that allow the various actors to participate.

Interdisciplinary practices within the sciences (e.g., biophysics), between science and engineering (e.g., bioinformatics), or in integrative studies (environmental sciences) occur within a shared episteme of the scientific method. Many sciences can be described as technosciences (for example, genomics or many subdisciplines of astrophysics such as gravity wave astronomy) because their scientific agendas are so heavily coupled to technological ones. These connections facilitate cross-disciplinary work, and the

Information Technology focus of *Beyond Productivity* foregrounded such shared connections, for example, through shared tool development. The expansion from an IT-centric focus to include the broad ranges of physical and life sciences, as well as the disciplines of design and humanities, complicate significantly the required approaches. Sheldon Brown's *Scalable City* (fig. 3) articulates multiple layers of complexity by combining IT with arts and humanities to envision an interactive, virtual world.

The demands of such interdisciplinary work, including differing heterogeneous loci of practice and epistemic methodologies, create very strong asymmetries that entail particular levels of risk and possible conflict. (The current stresses in the humanities due to the emergence of the digital humanities are emblematic). A number of White Papers report on SEAD collaboration failure because of such problems.

Some of the points of conflict are shared by all interdisciplinary practices, particularly in emerging areas. Promotion and tenure in universities is particularly problematic both because of sociological resistance and the inability to use standard metrics (e.g., publication in established peer-reviewed journals) and the difficulty in evaluating new scholarly practices (e.g., how to evaluate the work of an art historian who works with physicists when there are no physicists in the evaluation committees). We have noted the emergence of a cohort of "hybrid" professionals whose training includes a higher education degree in science or engineering and a separate one in arts, design, or humanities. Most importantly, the dearth of postdoctoral funding within the arts and humanities immediately privileges certain pathways and creates other asymmetries.

Funding organizations have occasionally responded to these issues by setting specific interdisciplinary funding programs (for example, the INSPIRE awards at NSF and the new AHRC Hubs in the United Kingdom) but there remains an across-the-board problem of evaluation.

Other asymmetries exist when collaborators are situated in industry or municipal institutions. Such collaborators may not

have what are called “terminal degrees” in the United States (e.g., a PhD or MFA), which can create conflicting situations in terms of funding attributions (for example, researchers in the gaming and entertainment industry often cannot be certified for teaching). We have mentioned elsewhere the stresses that differing intellectual property cultures can contribute to these problems.

We have the impression from our limited sample of SEAD demographics there are far more artists, designers, and humanities scholars working in SEAD collaborations than there are disciplinary scientists. There are many artists-in-residence programs in science institutions, but almost no scientists-in-residence programs in arts, design, and humanities programs. We suspect that this is not inherent in SEAD collaborations, but is a sociological asymmetry.

Though many of these issues face any interdisciplinary or transdisciplinary effort, SEAD practice faces particularly challenging obstacles because of a large variety, and depth, of asymmetries; this action cluster would be worthy of in-depth study and elaboration on best practices that could overcome the obstacles posed.

## **INCLUDING: Spurring Innovation through Diversity**

### **4. Communities Addressing Global Issues and Local Solutions**

Inclusion in SEAD activity may mean consideration of under-represented groups as collaborators or audiences, on the bases of culture, gender, geography, age, and skills. This is desirable for both societal and pragmatic reasons, ones motivated by current creativity and innovation theory. The internationalization of SEAD practice also foregrounds cross-cultural issues.

Many authors emphasize the need to support public projects that raise awareness of and the level of public discourse about science and technology. Accessible data visualizations are among the means that could promote understanding of the sensing and representational capabilities of various media technologies. Suggested supporters of such efforts include UNESCO as well as groups in the United States such as the National Endowment

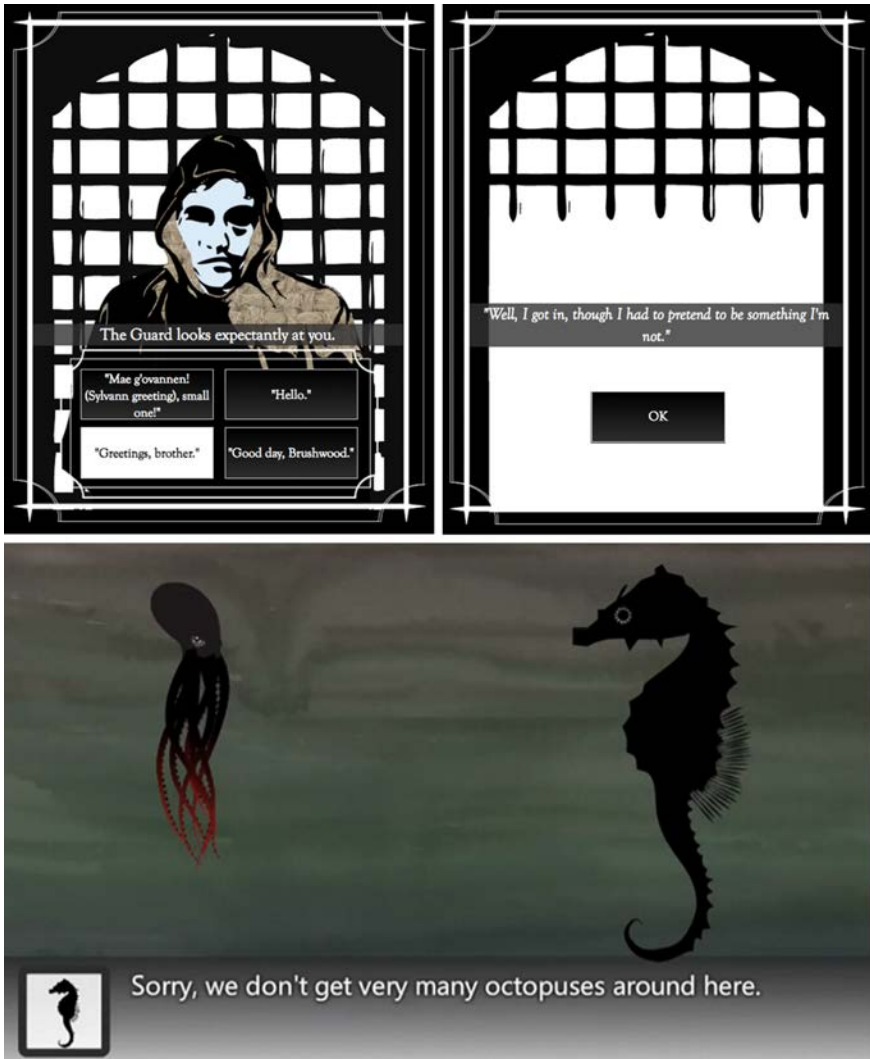


Fig. 4. Chimeria: Gatekeeper and Mimesis. These two projects use computer science, cognitive science, artificial intelligence, and sociology to model and study cultural phenomena. Chimeria: Gatekeeper (top, 2014) models social categorization and stigma; Mimesis (bottom, 2012) models experiences of "microaggression," everyday small acts of discrimination. Developers: D. Fox Harrell and the MIT Imagination, Computation, and Expression Laboratory. Photo © D. Fox Harrell. <http://groups.csail.mit.edu/icelab/content/projects>

for the Arts, the Foundation for the Alliance of Community Media, Centers and Institutes for Digital Literacy, the National Foundation for Educational Research, and the National Research Foundation. Authors encourage entrepreneurial approaches from such agencies, for example, by funding artistic works and then selling the results in order to recoup funds. A philosophy of “trade—not only aid” could help to encourage good-quality work and could create and sustain a market for science- and technology-based art.

Arts organizations, museums, and art magazines often focus on elite audiences, but extending beyond these groups could increase both transdisciplinary collaborations and the sharing of knowledge and expertise across broader demographic segments. A survey of works of art in various new media in museums, galleries, universities, and agencies could be instructive about different communities’ values, tools, and methods. Equally revealing would be the websites and online portals that support dialogue about such varied works and the theories that inform them. For example, to model and study social categorization and stigma, D. Fox Harrell and his research group, the MIT Imagination, Computation, and Expression Laboratory, use computer science, cognitive science, and sociology to inform their AI-driven interactive story *Chimeria: Gatekeeper* and interactive game, *Mimesis* (fig. 4).

Many communities are acknowledging creative industries as an area of economic development. Design and manufacturing are increasingly emphasized in the United States and Taiwan. Some authors suggest that industry in Asia would benefit from transdisciplinary research involving science- and technology-based creative work. SEAD work could serve as a catalyst, reducing costs and increasing production in developing countries. Already, developing countries are benefiting from low-tech and DIY protocols and tools, though challenges persist. For example, some authors encountered technical problems exacerbated by extreme weather and environmental conditions that interfered with the operation of mobile phones. Cameras on mobile phones also prove unreliable for some SEAD fieldwork; the lack of



resolution and inability to zoom results in lost details of insects and fungi being studied. Other pragmatic concerns present even greater difficulties, such as maintaining financial stability among farmers and scaling up successful technology-supported agricultural strategies.

Some authors envision an inclusive, transdisciplinary research agenda based on global-scale networks, including programs for graduate students to visit developing countries and conduct workshops or otherwise assist local researchers. Research in developing countries tends to be “authentic,” embedded in the local communities and engaged with people’s real and immediate needs more so than involving large-scale stakeholders and actors. Open-source hardware, open data, and open-access platforms and methods often prove useful. Authors suggest supporting science and art “ambassadors” who use low-tech solutions and citizen-science kits in order to share scientific protocols with various communities around the world. Farmers in particular could benefit from using mobile networks and learning to adapt them for their own needs.

Scientific entities organizing international conferences and symposia could include science-art exhibitions and talks on the benefits of science-art interactions. Organizers of art and science shows and fairs could promote inclusion by encouraging SEAD practitioners from developing countries to participate and by providing them with concessions and fee waivers. Promoting new works along with traditional art could have intercultural as well as educational benefits. Some authors believe this need is particularly strong in Asia. They suggest making deals with relevant cultural bodies to enable SEAD work; they note additional needs, including peer review processes, policy development, and the establishment of cohesive linkages among various community organizations. Global-scale collaborations could also benefit from a cross-cultural research program in which students in both the arts and the sciences could find interesting topics to develop. A globally shared and accessible “knowledge bank” could become a reference for topics and emergent SEAD curriculums. Wider adoption of the model of the practice-based doctorate could also support SEAD collaborations.

Authors suggest that funding bodies, research foundations, and creative institutions work with federal technology programs and organizations targeting SEAD-related work—as well as with individual stakeholders such as artists, scientists, and researchers—toward realizing creative projects and effectively promoting media literacy. We need to celebrate partnerships among creative individuals and industries that result in broadly useful new technologies. We also need to encourage entrepreneurship and work to overcome financial barriers limiting start-ups' access to new technologies.

Sensitivity to contexts and existing cultures requires special care when engaging in a cross-disciplinary collaboration. SEAD collaborators need to maintain openness, flexibility, trust, respect for a wide range of practices in acknowledging authorship and credit, and receptivity to challenges to one's values.

Authors note that academic programs in media literacy and media arts attract more members of minority groups than other technology-oriented programs. Therefore, supporting media-oriented programs may help to counter persistent demographic imbalances among students and ultimately practitioners working with new technologies. Using media-technology strategies for public communication about science and technology topics could also foster greater readiness for scientific study.

Increasing interest in soft materials such as thread and yarn have potentials to improve STEM learning related to computer programming and mathematical topology. Authors suggest involving children in “sewable computing” knowledge and practices, to lay the groundwork for increased mastery of STEM skills and to increase women's participation in the electrical engineering and computer science professions. Workshops that use hyperbolic crochet, fiber arts, and other creative crafts could also reduce math anxiety and open effective and supportive pathways into math learning. Arts and crafts activities may level the playing field also for individuals from low socioeconomic backgrounds.



## **EMBEDDING: Public Engagement and Negotiation**

### **5. Outreach, “Citizen Science,” Dissemination**

Authors suggest reaching out to communities through a range of involvements that includes not only increasing awareness, but also actively involving community members in SEAD-related work. Authors note that print publications, websites, and videos can function as means for increasing awareness about the importance of interdisciplinary collaboration. Documentary films are especially cited as a medium for showing how precedents of prior collaborations among scientists and artists continue to be informative. Industry and government agencies are encouraged to note examples of early artistic experiments in digital media that have led to technological innovation. Such examples include games, simulations, human-computer interfaces, and multimedia search engines. These developments argue for better recognizing and supporting the role of artistic creation in economic and cultural advancement.

Relationships between industry and community organizations could support development of programs for people of all ages, in order to communicate results of scientific research and involve community members in creative activities reflecting scientific knowledge. Interactive seminars may be a way for artists, scientists, and the lay public to find application areas for knowledge generated by SEAD projects. Local TEDx (<https://www.ted.com/tedx>) venues, or other regular venues such as the Leonardo LASERs and those offered by other groups and organizations, are another way of attracting audiences and encouraging collaborations. In *Particle Falls* (fig. 5), Andrea Polli provides a forum for discussion of local and global challenges surrounding air quality via a participatory, public installation. Meetup methodologies used in the hacker and maker communities are also effective.

Some authors describe a notion of “grassroots innovation” in which not only professional researchers but also community members engage in participatory design of potential solutions to local and global challenges. These authors call for local employers



*Fig. 5. Particle Falls. A large-scale projection that allows viewers to see current levels of fine particulates cascading down the facade of the AT&T Building in San Jose, CA. 2010. The project includes a nephelometer, donated by Met One Instruments, which measures the smallest particle, PM2.5. Fewer bright particles over the waterfall mean fewer particles in the air. Presented in the cities of San Jose, Detroit, Philadelphia and Pittsburgh. Partners: Andrea Polli with Tim Dye, MetOne Instruments, special-effects designer Chuck Varga, and members of the Social Media Workgroup including Eric Geusz and Ryan Romero. Photo © Andrea Polli. <http://www.vimeo.com/16336508>.*

and members of city councils and other government agencies to acknowledge and support community-based creative spaces such as FabLabs, Maker Faires, wet labs, and hacker spaces. Job opportunities and calls, bids, and contracts for specific projects could be situated in these alternative R&D spaces. Projects especially well suited for such spaces might include disaster management, forms of civic engagement promoting ecological

stewardship, “smart cities” efforts, and deliberation about ethical issues related to emergent technologies. Community collaborators could help to both develop new technologies and identify culturally appropriate applications. Urban farming is getting particular attention as an area orchestrating multidisciplinary expertise and promoting sustainable communities. Many authors note the importance of initiatives to encourage entrepreneurship, especially in rural communities.

Authors call for creation of maps, using new visualization approaches, to illustrate correlations of concepts in SEAD projects, geographic locations of collaborators, and so on. These authors also suggest sharing such maps broadly, through widely read science and art publications and general interest publications prepared for well-informed audiences. Many authors suggest creation of websites, including weblogs, to document SEAD projects of regional, national, and international scope. The XSEAD initiative (<http://xsead.org>) offers an online gallery and forum that documents SEAD works and supports discussion among practitioners.

A refrain emanating from several authors to provide more funding encouraging interdisciplinary work emphasizes the varying scopes of SEAD projects and the associated needs for both involving community members and disseminating project results to communities of different scales. Authors express the hope that both national-scale funding entities and universities will heed these suggestions.

Authors also stress that both curriculums and university structures need to evolve in order to encourage transdisciplinary work. Generally, tenure tracks persist within rather than across colleges, and this tends to be true even at the departmental level. Funding initiatives often exist in silos as well. Authors suggest creation of project grants, scholarships, and fellowships for students and faculty working in interdisciplinary fields. Science and engineering faculty, graduate students, and postdoctoral researchers often need specific encouragement to work with transdisciplinary arts interests. These curriculum development

issues were discussed at length in the 2003 *Beyond Productivity* report, but once again, the extension of these ideas beyond IT poses real curriculum development challenges, which are being addressed in a variety of venues that bridge existing educational structures and those within civil society more broadly.

One candidate area for cross-over activity could be workshops that “bring together choreographers and dancers, cognitive scientists, neuroscientists, and other academicians, scientists, and those in digital media and other technologies” (Batson 2012) to frame one-year projects advancing knowledge from their combined perspectives. Soft materials such as yarn, and arts and crafts generally, present additional opportunities to promote transdisciplinary collaboration and STEM learning. A simple crochet pattern, for example, can yield models of hyperbolic planes that make mathematical concepts accessible. These are concepts that otherwise might seem elusive. Authors encourage public arts institutions and other community organizations to work with schools in creating a synergistic system through which people of all ages can engage, learn, and enjoy the mathematics underlying such creative activities. One author calls specifically for development of workshops to reduce math anxiety in teachers, parents, and students. In these workshops, “hyperbolic crochet, fiber arts, creative craft, and other engaging and non-threatening activities can open an effective and supportive pathway into math learning” (Kuhn 2012). Authors note that arts and crafts designed to promote STEM education could be effective not only in schools, but also through community programs including both formal and informal mentoring, arts-related business initiatives, and outreach programs associated with museums, symphonies, and other public arts institutions. The increasing interest in arts and crafts could argue for cross-institutional sharing of materials, spaces, and other resources.

Authors suggest increasing outcomes-based interdisciplinary courses for both undergraduate and graduate students, to help students gain fluency in areas of intersection between disciplines. An initial challenge would be in breaking through preconceptions about the perspectives. Such courses could be

offered as single electives or as part of an overall campus vision for transdisciplinary learning. Authors also point out advantages in developing a comprehensive study of cross-disciplinary course curriculums, as could be initiated through organizations such as the United States–based College Art Association, Art & Science Collaborations, the Leonardo Education and Art Forum, the National Science Teachers Association, the Mediterranean-perimeter–based YASMIN, and numerous other international organizations active in SEAD.

Authors further suggest that a new call for courses be initiated through SEAD (<http://sead.viz.tamu.edu/>). The resulting body of work could encourage collaboration and diminish the isolation so often experienced by SEAD-oriented researchers and educators. Inventorying the results in a dedicated website could ease comparison of transdisciplinary efforts, which may help to heighten quality as educators share information about their curriculums through the platform. Helpful functions would include a cloud-based resource of syllabi, a blog, links to best practices in interdisciplinary curriculums, and announcements of international conferences in art-science-humanities. One author suggests expanding the SEAD subgroup, Curriculum Development in the Arts, Sciences, and Humanities (CDASH; <http://www.utdallas.edu/atec/cdash/>) to include such functions; XSEAD, HASTAC and other emerging platforms are other possibilities. Authors suggest tie-ins to existing academic journals and websites. Ideally, the emerging platform would facilitate pooling of expertise and resources for innovation among educational institutions internationally. Of course, such web resources could extend to become teaching tools, used along with other media such as documentary films.

The means through which SEAD work is disseminated—printed and Web-based publications, films, videos, and social media—can also be the means of recruiting collaborators and forming partnerships. Transmedia can also be helpful in co-developing projects and workshops. Authors suggest tapping yet-unrealized uses of the interactive capacity of mobile media. The example of e-agriculture, in particular, suggests opportunities for employing

a multidirectional model of communication, in which every node of the network can be both a consumer and producer of information. Beyond receiving expert information through a hierarchical mode of one-way transmission, farmers could send responses and perhaps data from the field, to form a more egalitarian and information-rich exchange. In the realm of dance, partnerships with members of businesses and larger communities could meaningfully broaden experimental studies. Sample topics might include Problem-Solving in Business through Dance; Improving Learning through Attention Development (perhaps especially for high school students); Dance and Health; Memory and Movement in Aging; and Dancing with Challenges (as in developing new therapeutic treatments for Parkinson's Disease).

## **SITUATING: An Emerging Ecology of Creative Places**

### **6. Alt Spaces**

In parallel with the increase in distributed resources such as open-source software and MOOCs (Massive Open Online Courses), more and more SEAD-compatible places for meeting and making are appearing in local communities. DIY (Do It Yourself) and DIWO (Do It with Others) organizations, known as Fab Labs, hacker spaces, skunk works, and maker places, provide shared access to knowledge and technologies. Such places can answer authors' calls to support decentralized, flat, peer-to-peer, and community-focused organizational models. These places can also serve as incubation centers and showcases for technology and manufacturing companies. Such "alt spaces" promote a culture of tinkering and STEM inquiry through self-directed, creative interaction with materials. "Thinking with things" can bring people together and provide powerful ground for learning scientific and artistic principles, as Katherine Moriwaki and her partners demonstrate through gadgITERATION, a youth development program and hardware platform for novice engagement in electronic tinkering (fig. 6). The project aims to lower barriers to the design and production of interactive, electronic objects.





*Fig. 6. gadgITERATION. A youth development program and hardware platform that encourages novice engagement in electronic tinkering. The project aims to lower barriers to the design and production of interactive, electronic objects. Collaborators: Katherine Moriwaki, Louisa Campbell, Jonah Brucker-Cohen, Joe Saavedra, and Liza Stark of the School of Art, Media, and Technology at Parsons the New School for Design. 2012–present. Photographer: Decho Pitukcharoen, © gadgITERATION. [www.gadgiteration.org](http://www.gadgiteration.org).*

Authors who support these initiatives call for careful research and evaluation of these learning effects. Some suggest that universities could promote transdisciplinary collaboration and residencies in community-based alt spaces as general requirements for career advancement. Permanent spaces such as fabrication shops and resource-rich lab-studios are also needed on campuses to support SEAD work and learning. Libraries and university centers on- and off-campus could provide spaces for mixed-age school groups to access materials and engage in design projects. Benefits of

the networks of places and people created through alt spaces have been demonstrated in many communities, but in some areas there are regulations inhibiting wet-lab experimentation outside of university settings, which may be slowing innovation. Broader involvement of community members can be achieved through art and design competitions, crowd-sourcing idea generation, and “citizen science” initiatives. Stakeholders might include community members, city councils, faculty and practitioner researchers, galleries and artist collectives, museums, public libraries, funding agencies, and chambers of commerce. Networking across geographic sites, perhaps internationally, could form a set of think tanks for co-creative transdisciplinary work.

A large number of Suggested Actions target specific strategies. These new social developments are becoming crucial components of the SEAD landscape, but there has been little study or investment into how to build sustainable networks of intervention.

## **SENSE-MAKING: Multimodal Knowledge and Ways of Knowing**

### **7. Integrating Understandings through the SEAD Perspectives**

The value in building a comprehensive understanding of human cognition and perception, in all its complexities, is a thread mentioned throughout the White Papers. Sense- and meaning-making are central agendas, with many authors striving to avoid reductionist approaches that fail to capture the integrative natures of human experience and creativity. Even if not advocating for a specific modality or research area, authors are apt to mention the need to secure funding for cognitive research and the need for research that connects the understanding of learning processes and K-12 SEAD education with both higher education and the community at large. Authors also used the term “embodied cognition” frequently to express the need for seeing connections between the body, the brain, and the sweep of human experience.

Many authors wrote about sense-making from personal experience, explaining how their transdisciplinary foundation aided them as adult professionals. Specific topics include





*Fig. 7. Living Wall. An interactive wall painting made from conductive paint, magnetic paint, traditional paint, and custom circuit boards. Developers: Leah Buechley, David Mellis, Bonifaz Kaufmann, Hannah Perner-Wilson, Emily Lovell, and Kanjun Qiu, Tshen Chew, and Jie Qi of the MIT Media Lab. 2009. Photo © Leah Buechley. <http://highlowtech.org/?p=27>.*

projects developed to stimulate learning, particularly in K-12 environments; perception studies; embodied cognition; how movement (e.g., dance) aids cognitive research; and the use of code to engineer sound (audio) projects and blend SEAD perspectives. Authors also document the growing body of research on specific “design thinking” that is fundamental to the intersection of the sciences, engineering, arts, and design. Several authors point to studies that show arts training is associated with higher academic performance, such as those published by the Dana Foundation (Gazzaniga, Ashbury, and Rich 2008; Posner et al. 2008). Many

authors advocate for such “evidence-based” approaches. Leah Buechley et al. utilize design thinking in *Living Wall*, interactive LED wallpaper that integrates technology, design, the senses, and the body (fig. 7). It can be programmed to monitor its environment, control lighting and sound, and generally serve as a beautiful and unobtrusive way to enrich environments with computation.

Our external reports expanded on the suggestions, with some offering specific examples that demonstrate the value of collaborative work in sense- and meaning-making. The “Painter’s Eye” project, funded by the Wellcome Trust Sci-Art program, was one such example. Undertaken under the leadership of filmmaker and scientist Dr. John Tchalenko and neuroscientist Chris Miall, this 1998 Sci-Art-funded project involved the collaborative efforts of the portrait painter Humphrey Ocean as well as a team of scientists from Oxford and the United States. The initial exploration opened up new ways of thinking about how portrait painters work. London’s National Portrait Gallery exhibited the scientific work and the collaborators later received additional funding that allowed them to make more discoveries about the physical and mental processes involved in portraiture (Wellcome Trust 2002).

Key concerns in the sense- and meaning-making areas intersect with those raised in other SEAD action clusters: How do we understand collaborative working methods scientifically? The NSF-sponsored “Art as a Way of Knowing” conference, organized by the Exploratorium, focused on how different ways of knowing can interact productively (McDougall 2011). Robert Root-Bernstein and Michelle Root-Bernstein’s White Paper analysis of successful scientists and engineers highlights the role of arts avocations in their work (2012). A prevalent interest in how the various human senses “play” together is reflected in reflections on sonification, haptics research, and embodied knowledge. Does the specialization scientists bring to creative research projects obscure artistic contributions and knowledge, and vice versa? How do we develop strategies that aid in building cross-disciplinary vocabularies, tools for SEAD collaborators who are inexperienced in specific types of relevant research, and

other support mechanisms for working together in research and evaluation? Authors also mention less direct but equally important considerations; the need to comprehend protocols for human-subjects research, for example, brings larger social goals into play when developing a scope of research. Additional “sense-making” activity areas noted include neurosciences, cognitive sciences, and life and health sciences, as well as human-computer interaction and human-centered computing.

## **DOCUMENTING: Recording and Transmitting**

### **8. Capturing, Publishing, Curating, Archiving**

The SEAD community of practice finds itself innovating in both the form and content of their research and creative practice. In general they have been “early adopters” and often developers of new forms of multimedia arts and performance. They are also innovators of research methodologies and modes of collaborative scholarship. Though these claims are not specific to the SEAD area, they involve specific obstacles and opportunities that a number of the SEAD authors identify. Many of the transformations underway—such as open-access publishing, multimedia and online publishing, social media, and new forms of scholarship—are accentuated because the SEAD community of practice bridges very different disciplinary cultures. Complications arise from differing practices with regard to intellectual property and authorship, modes of documenting work, and sharing work with peers and broader audiences. Several of the White Papers emphasize concerns about conservation and archiving of unstable media and preservation of the work of pioneers in the field. Again, this concern is not specific to the SEAD area, but it becomes particularly acute in the transdisciplinary context, and thus deserves attention. The priority given to this area is signaled by the sibling XSEAD project, which is developing an online interdisciplinary platform for documenting and showing work, both scholarly and creative; a number of other platforms are also under development internationally.

It is clear that the SEAD community will be engaged in many experimental and innovative approaches, which could be

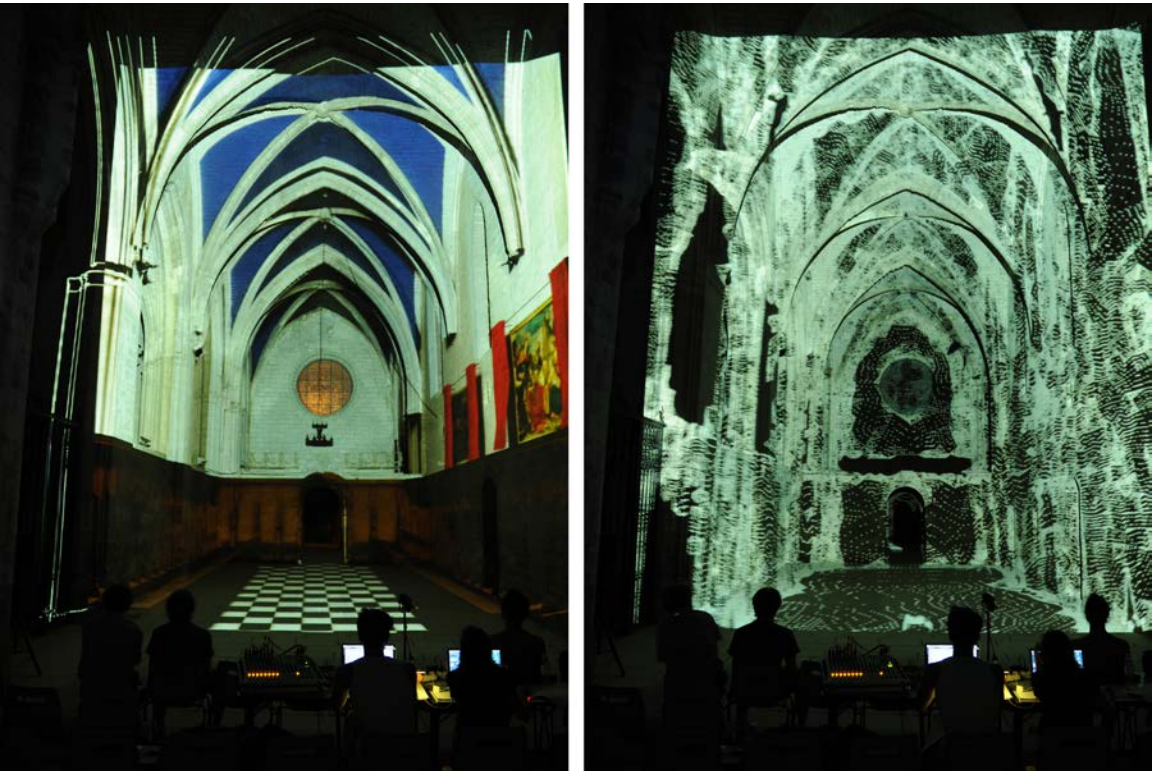


Fig. 8. *Genius Loci*. A multimedia theater performance in the church of Chartreuse, Villeneuve-lez-Avignon, that explores how digitalized heritage can be used for situated performance. 2011. Co-creators: Veronique Caye (direction), Livio de Luca and Christian Jacquemin (images and augmented reality), Aurélie Favre-Brun (history), and others. Produced by the Laboratoire Victor Vérité, La Chartreuse of Villeneuve-lez-Avignon. Supported by the CNC-Dicréam, by LIMSI-CNRS, and by Laboratory MAP-Gamsau (CNRS/MCC). Photo © Aurélie Favre-Brun.. <http://www.victorverite.com/content.php?cat=spect&actu=genius>.

transferable to other areas of research. Several authors address forms for publishing, documenting, archiving, and curating of both original works and the scholarship surrounding them. One group working in innovative ways to explore and document meaning and history is the Laboratoire Victor Vérité. *Genius Loci* demonstrates how digital heritage can be used for situated performance to recapture the spirit of La Chartreuse, a medieval church complex, in Villeneuve-lez-Avignon, France (fig. 8). It is important to note these “infrastructure” issues, which are driven



in large part by digital capabilities and which bridge those of other interdisciplinary research areas.

Scholarly and professional societies and organizations that have played key roles in these areas during the past fifty years themselves are undergoing rapid evolution and restructuring. Resolving these new methods will require the kind of rethinking espoused by Cathy Davidson and David Goldberg in their report, "The Future of Learning Institutions in a Digital Age" (2009).

## **LEARNING: Tapping into the Passion and Creativity of Lifelong Curiosity**

### **9. Sharing Blended Experiences**

Blended learning experiences transect all forms of formal and informal education. In the past ten years there has been an increase in the number of higher education programs that house faculty from multiple disciplines (Evans 2012). Some middle schools include traditionally structured arts programs to bolster STEM learning. SEAD discovered 35 charter schools in the United States with the title of "STEAM Academy." Among them, the "A" is defined unevenly, attributed to "applied mathematics," "aeronautics," "humanities and language arts," and "arts." Common Core curriculum standards intended to address the needs of a global economy are embraced by 45 states (Council of Chief State School Officers 2013). In the United States, from the Bush administration's "No Child Left Behind" act to the Obama administration's "Race to the Top" initiative, learning continues to be largely defined as the acquisition of separately delivered skill and knowledge areas.

To assess the value of transdisciplinary learning, there is a need for research that can identify, examine, and evaluate relevant theoretical frameworks. Theories of embodiment, which address forms of knowledge and learning related to hands-on and project-based experiences, have been developed within the fields of philosophy (Husserl 1983), architecture (Downing et al. 2008), art (Penny 1997), mathematics (Nemirovsky and Ferrara 2009), and others. Related studies in cognitive learning, theories of

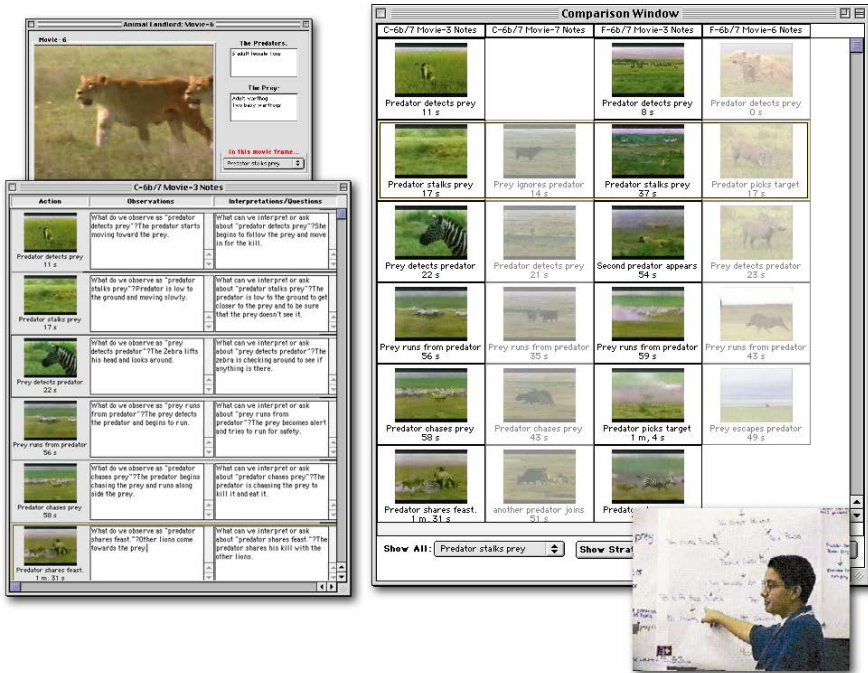


Fig. 9. Animal Landlord. A video annotation tool for biology classrooms. Students create their own narrations of documentary films to learn about ecology and evolution. Developers: Brian K. Smith, Drexel University, and Brian J. Reiser, Northwestern University. 1996. Photo © Brian K. Smith. <https://www.sesp.northwestern.edu/docs/publications/9145369244049e34af079.pdf>

emergence and affordance, and literature about technology-based knowledge transfer hold potential to contribute to such understanding (Williams, Mackness, and Gumtau 2012).

Other data that can contribute to understanding of SEAD learning includes statistical factors on graduation rates, higher education enrollment, career entry data, and results from standardized testing. Human factors such as attitude and self-identification of professional expertise can provide a basis for understanding relationships between blended learning experiences, excitement, and engagement. Impacts resulting from “design thinking” can provide knowledge about creativity that catalyzes work force

development. Valuable input from studies of engagement by under served populations may be applicable to other population segments, for example, literature on the role of family and community in the learning process (Lewis et al. 2010).

SEAD learning enables invention and innovation by blending the arts and sciences. As a partial legacy of formal education, “hacker spaces” and “maker spaces” proliferate but are not usually engaged in established research frameworks that can provide understanding about the excitement they have engendered and the potential they offer. Such community spaces provide a rich ground for research on “thinking with things” (Kuhn 2012).

Many tools to support SEAD learning have been developed. Open-source frameworks such as Processing, kits such as Instructables, and creativity support tools proposed by NSF-funded projects (including the now-archived CreativeIT program) have built a rich repository to research best practices (CreativeIT 1999). *Animal Landlord*, an example of inquiry-based learning, uses video annotation tools to examine clips of lions in the wild and in zoos to help children practice scientific skills of observation and articulate theories about lion behavior (fig. 9). While such tools have been studied as closed systems, more work is needed to assess the impact of learning with multiple tools, as well as to broadly assess how they contribute to computer literacy (Presley 2012).

If these areas for research are further articulated, new ground can be gained to establish SEAD learning as a powerful way to address twenty-first-century networked learning. Imagine K-12 administrators embracing research programs and public service components that take on grand challenges; broad-scale partnering across different domains that link formal and informal, private and public groups and resources; and models that help to structure inquiry-based learning for all ages.

An ecological model is a valuable metaphor for envisioning learning experiences based on a systems approach. Pedagogical improvements include a move to decentralized, distributed, and integrated forms of learning that mesh with the organic

structure of information flow. Courses that examine and compare methodologies and tools employed by artists and scientists can foster understanding of process and outcomes across disciplines. Student-centered models redefine faculty as facilitators or co-creators of knowledge. There is a need to support real time, virtual connections between classrooms and private, corporate, and research groups that can help them become self-organizing and less hierarchical (Cenkl 2012).

Coalitions among private foundations, corporate entities, and learning institutions have recently blossomed. Challenge projects and service-based learning models have activated partnerships between middle and higher educational institutions. Urban areas and those near research and business centers are in a better position to leverage support to benefit local and regional economies. Rural areas without access to institutions of higher education need collaborative networks for resource sharing. Home schooling groups and community maker spaces would benefit from increased access to networked facilities and resources. Initiatives to improve local economies can be bolstered with structures that support global outreach and collaboration (Quintana and Quintana 2012; Brown 2012).

While partnerships among higher education, business, and K-12 schools are more frequent today, they are often led by visionary individuals; when these individuals change focus or lose funding, the partnership often ceases. The contextual nature of such collaborations cannot be reproduced in an overarching way, but it is entirely possible to create a structure of support for matchmaking to broker and resources to stimulate customized partnerships on larger scales. Building partnerships can involve developing curriculum that spans multiple levels and provides a smoother transition to higher education or career entry. Networks can focus on initiatives to resolve issues such as accessibility, resources, formal-informal partnerships, professional development, materials and resource collections, and opportunities for training. Exemplars of SEAD learning could partner to develop a practitioner- and designer-generated taxonomy of courses to build best practices (Williams, Mackness, and Gumtau 2012).



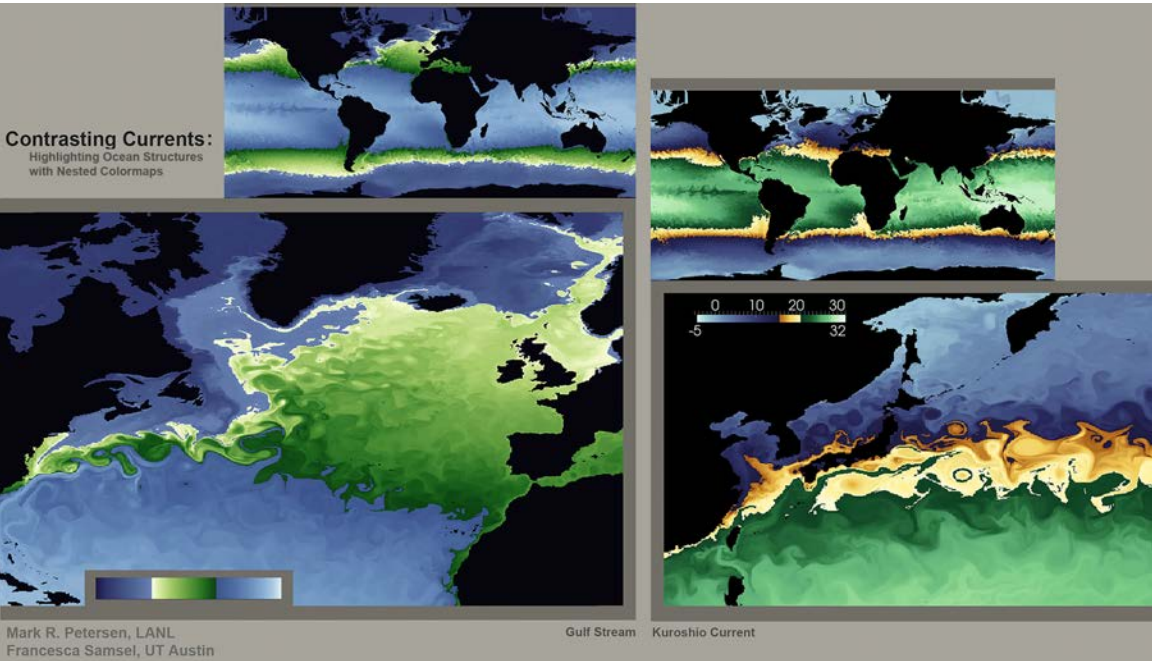
SEAD's vision for lifelong learning brings together three important concepts for an ecological transition to twenty-first century learning: innovation, creativity, and inclusion.

We envision twenty-first-century learning as a dynamic system by those of all ages who employ multimodal and perceptual approaches alongside analytical, statistical, and computational ones. Such learners will creatively formulate the right critical questions to ask of technology, and—appropriately—will then assign to computational systems the most critical problems to solve.

### **COLLABORATING: Methodologies Working across Disciplines and Institutions**

There are good reasons for establishing disciplinary practices, and certain problems require “drilling deep” into narrow areas of knowledge. Similarly, delimited human organizations are necessary to articulate functionalities and operational feasibilities. But many real-world problems require integrative cross-disciplinary approaches that require partnering between different kinds of organizations. There is a large body of research on practice and best methods in academic, commercial, and municipal contexts to accompany practices that require collaboration and partnering. We have been struck by the large amount of literature on interdisciplinary, integrative, and holistic studies and the emphasis that many prior reports place on recommendations that address the collaboration problems faced by individuals and organizations. Recent work, for instance by Allen Repko and William Newell, has led to substantial consolidation of interdisciplinary theory and practice (Repko 2007; Repko 2012; Repko, Newell, and Szostak 2012).

The work of SEAD practitioners draws on this prior body of collaboration practice, but the broad range of disciplines involved poses particularly hard problems. There are different scholarly practices in many of the arts and humanities that privilege the individual artist or scholar. Intellectual property regimes vary and are changing across SEAD research. Methods for showing work to communities of peers and the larger public are heterogeneous.



*Fig. 10. Contrasting Currents: Highlighting Ocean Structures with Nested Colormaps. Visualizations of ocean structures, produced in collaboration between a visual artist and a climate-modeling scientist, which offer increased detail of the data within the climate change models. Co-collaborators: Francesca Samsel, University of Texas at Austin; Mark Petersen, Climate Ocean Sea Ice Modeling Group, Los Alamos National Laboratory; and James Ahrens, Data Science at Scale, Los Alamos National Laboratory. 2014. Photo © Francesca Samsel, UT Austin. <https://datascience.lanl.gov>.*

Institutional cultures vary extremely, from individuals in large companies or universities to artists in collectives; systems for validating individual merit and public recognition are dissimilar. In reviewing the White Papers and the Suggested Actions, we note consistencies in the obstacles and difficulties reported, yet there is a lack of any systematic collaboration methodologies or explicit acculturation to reconcile diversities. Networked culture creates additional situations and needs including the rapidity of interactions, mid-level partnering across organizations, and the mixing of online and physical collaborating. There have been significant investments in science and engineering for developing

collaboration platforms and systems that often are not present in the arts and humanities, creating additional asymmetries that challenge collaborative practice. Some examples of SEAD consortia exist in Europe due to funding mechanisms that favor multinational, multidiscipline formal collaboration networks. Yet very few SEAD practitioners have any formal training in collaboration techniques and best practices, except within project management training. It is clear that the improvement of collaboration methodologies that span the range of disciplines often faced by SEAD practices is a key area for study and development.

*Beyond Productivity* already highlighted the issues surrounding the need to address collaboration methodologies. In particular the authors referred to the work of Mihaly Csikszentmihaly, who articulated a systems view (1988, 326) and spoke of the need to articulate a social system made up of individuals, knowledge domains, and institutional structures.

## **10. Collaborations between Individuals and Disciplines**

SEAD practice requires individuals from differing disciplinary and organizational backgrounds to think, create, and work together, as visual artist Francesca Samsel and scientists Mark Petersen and James Ahrens do in their collaboration, *Contrasting Currents: Highlighting Ocean Structures with Nested Colormaps* (fig. 10). Many of these collaborations span national boundaries and many of the most successful collaborators are geographically mobile. The international character of collaborations is common in scientific and engineering projects, but less so in the arts and humanities. These groups also have differing value systems in articulating emphases on the global and the local. In reviewing the demographics (see Appendix 4) of our White Papers participants we were struck by other facts that have impacts on SEAD collaboration practice: (1) Our participants are almost exactly gender balanced, even though we followed no particular recruiting approach. This gender equity appears to be characteristic of the SEAD community of practice. (2) The majority of our participants are from the arts, design, and humanities (64 percent). Increasing the participation of scientists, engineers, and

mathematicians is an issue for further growth. (3) As noted above, we identified a cohort (20 percent of participants) whom we have called “hybrids”: that is, they have an advanced degree in one field of science, engineering, or mathematics, and a separate degree in a field of arts, design, or humanities. We have the impression more and more individuals are combining perspectives and effort in this way. Such individuals may play important translational roles in collaboration practice. Some White Papers authors point out that individuals used to working on their own who enter collaborative relationships need to maintain open-mindedness allowing for ongoing adjustments of preconceptions about partners’ disciplines. Likewise, educating fellow collaborators must be ongoing.

### **11. Partnering across Organizational Boundaries**

A wide variety of institutional structures underlies SEAD disciplines; this underpinning varies across the globe. In some countries, polytechnics are separate structures from schools of art and music. Entrepreneurial cultures also vary widely, as do connections between higher education and industry. As noted, much innovation has been occurring in “alt spaces” that form outside of conventional organizations. The traditional innovation “triple helix” of universities, government, and industry bypasses the loci of much SEAD creative work. As described in the “Situating” cluster above, SEAD practitioners are heavily dependent on mobility between formal and less formal institutional contexts; evolutions such as the Fab Lab movement have been one response to these emergent practices. Another is the Santa Fe, New Mexico–based, independent nonprofit 1st-Mile Institute that addresses local-global issues, including the project, *Mapping the Information Eco-Systems of the Colorado Plateau* (fig. 11). The heterogeneity of organizations that need to partner for successful SEAD collaborations poses legal, economic, and operational difficulties; future solutions to these challenges may need to depart from traditional funding agency models. Business practices include widely accepted approaches, such as Strategic Alliance methods, for raising the success level of partnerships. The introduction of programs for SEAD collaborators to learn such management methods could also benefit SEAD partnerships.

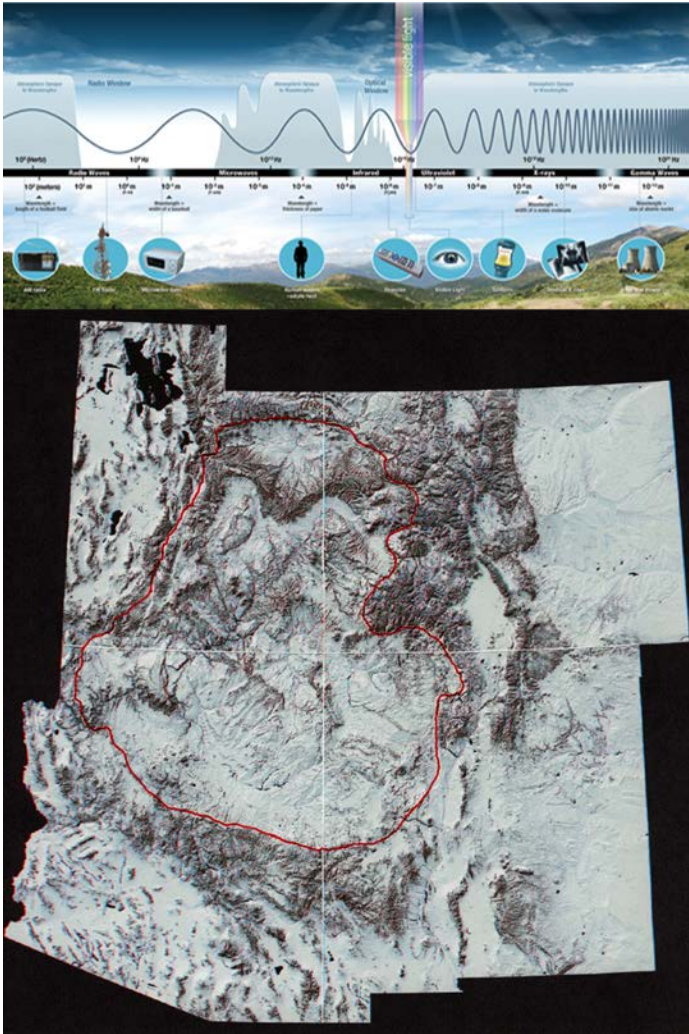


Fig. 11. The Information & Communications Eco-Systems of the Colorado Plateau: A Field Study. *Research Surveys + GeoSpatial Mapping + Digital Media + Photographs + Performance Arts + Narratives + Web.* A grounded environmental arts and sciences “field study,” complementing other regional “natural resources” studies and decision-support processes, being designed to collaboratively document, map, assess, and creatively present better understanding of the complex human and non-human “information and communications ecosystems” of the Four-Corner States’ Colorado Plateau. Creator: Richard Lowenberg, 1st-Mile Institute. 2014-15. [www.1st-mile.org/sarc.html](http://www.1st-mile.org/sarc.html).



## **THRIVING:** SEAD Ingredients as Essential Contributors to Healthy Communities

Many of our contributors raised concerns about the SEAD discourse both in terms of possible instrumentalization of the arts, design, and humanities but also because culture and values are often backgrounded in the kinds of issues and Suggested Actions that are proposed. Creativity and innovation are not goals in themselves, but means to enable thriving and healthy individuals, communities, businesses, organizations, and a sustainable planetary civilization. Science and technology, as means of knowing and being in the world, carry implicit and explicit values that can come into conflict with other human aspirations and must be articulated and negotiated with other systems of beliefs and social practice in our societies. Often such concerns are addressed through education outreach, public communication, and other secondary or parallel mechanisms to research and development (there are exceptions, such as the integrated approach in nanotechnology and society). The rapid growth of the creative industries and knowledge economies has in some cases been at the expense of investment and development of the arts and humanities that must be equal partners in SEAD strategies. One promise of the SEAD ambitions is to foreground such issues as part of the deeper collaboration strategies between practitioners in the different disciplines.

In recent years, economists have developed ways of taking into account well-being and happiness as part of understanding and comparing societal development at the level of individuals and groups. Health professionals insist that well-being requires a combination of factors, from biological to psychological, at both the individual and group level. A number of Suggested Actions engage with how ethics, values, health, and happiness, as well as joy and well-being, can be articulated as part of SEAD approaches.

### **12. Ethics and Values**

Historians and philosophers of science and technology have developed a good understanding of the way that ethical issues arise in the scientific method itself, in the social practice of science



Fig. 12. Prom Week. A game created through basic research on making social interaction playable, requiring novel computer science social simulation techniques that are guided by arts storytelling and humanities media studies approaches. Core team: Josh McCoy, Mike Treanor, Ben Samuel, Aaron Reed, Michael Mateas, Noah Wardrip-Fruin of the University of California, Santa Cruz. <http://promweekgame.com>

and engineering, and in the content of science and engineering. Historians, political scientists and social scientists have a growing understanding of how organizations and societies deploy deeper values and negotiate changing ethical landscapes. SEAD methodologies should seek to foreground issues of ethics and values and not defer them to secondary discussions outside of the SEAD community. The computer simulation *Prom Week* is a game made possible by basic research on making social interaction playable (fig. 12). *Prom Week's* AI approach has been adopted by the European Union FP7 project SIREN to create games that help children learn strategies for addressing cross-cultural conflict. As



a community of practice that straddles several disciplinary value systems, SEAD is uniquely placed to take leadership in these discussions.

### **13. Well-Being and Joyfulness**

The passions and dreams that drive the creative arts in all their varieties are essential contributors to thriving communities, from the deep cultural engagements of celebration and commemoration to personal joy and happiness. An expression of this is Jack Ox's *RrrumphTillfTooZiiUuu*, an 800-square-foot visualization of Kurt Schwitters's sound poem, "Ursonate, Movement I" (fig. 13).

The arts, design, and humanities are important approaches that in themselves contribute to healthy, sustainable societies; their contributions to the interplay of "ways of knowing" require an acknowledgement that investment must be made in both the "SE" and "AD" segments of SEAD practice.

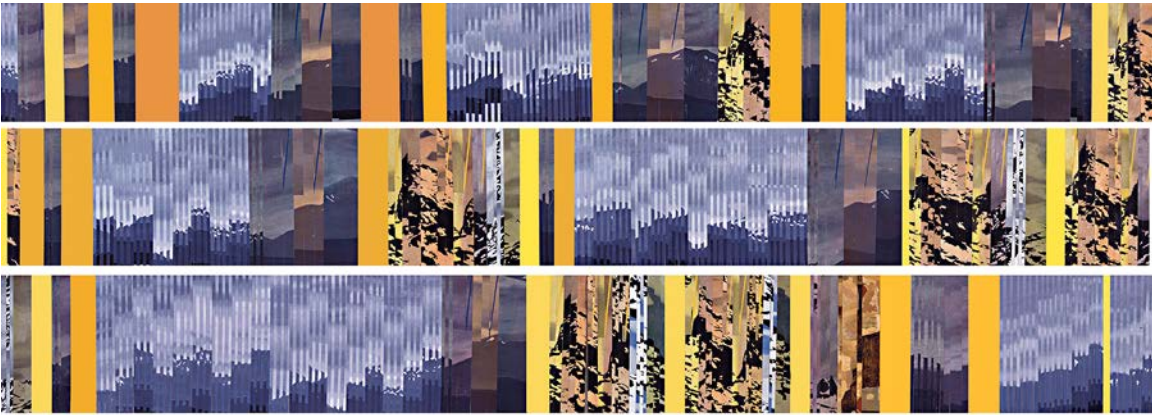


Fig. 13. RrrumphTillfTooZiiUuu. ““RrRrummpff tll? Rum!  
 RrRrRrRrRrRrummpff tillff tooo? Rum! RrRrRrRrRrRrRrumpf tillff toooo?  
 ziiuu! Rum! RrRrRrRrRrRrRrRrummpff tillff toooo ziiu enn ze! Rum!  
 RrRrRrRrRrRrRrRrRrummpff tillff toooo? Ziiuu ennze ziiuu.....” Sections  
 from an 800-sq-ft. visualization of Kurt Schwitters, “Ursonate, Movement  
 I.” Collaborators: Jack Ox (visualization) and Kurt Schwitters (author of the  
 sound poem “Ursonate,” 1922–1932). 1993. Photo © 1993. [http://www.jackox.net/pages/Ursonate/ur\\_MAINindex.html](http://www.jackox.net/pages/Ursonate/ur_MAINindex.html).

## CHAPTER 3

### SUGGESTED ACTIONS

The Suggested Actions presented in the White Papers, together with the action cluster framework, relate to our four framing objectives: culture and economic development; research and creative work; learning and education; and collaboration and partnerships.

Stakeholders can use this very rich set of specific Suggested Actions to develop strategies for enabling SEAD activities.

For comparison with the 13 action clusters, the *Beyond Productivity* (Mitchell, Inouye, and Blumenthal 2003) report proposed multilevel strategies around six targeted areas:

1. Providing new tools and media for artists and designers;
2. Providing opportunities to develop ITCP skills;
3. Creating environments that support ITCP;
4. Fostering the culture of information technology and creative practices;
5. A new form of research;
6. Making ITCP happen.

A comparison of that report and the outcomes of this SEAD White Papers study motivates a final overarching Suggested Action or “Call to Action”: we conclude that it is opportune to reconvene a national study, nearly 15 years after the *Beyond Productivity* report was initiated, with the scope of a new report emphasizing the expansion of the SEAD community of practice from IT-centric preoccupations to other disciplines of science and engineering, but also humanities and design; the growing international cross-coupling of SEAD groups and consortia; and a focus on societal and economic issues.

## Suggested Actions by Action Cluster

Below are the Suggested Actions for each of the White Papers action clusters. Author names correspond to the lead authors of the White Papers. The Suggested Action numbers correspond to numbered actions that authors themselves identified within their White Papers or abstracts.

### **TRANSLATING:** Problem-driven connections among academic, commercial, and civil societies

1. Project formation and translational value. Specific suggestions include the design of products, engineering, furniture, architecture; need-driven projects; societal uses; and scientific inquiry.

Author key: Challa 3, 4; Davis 6; Essl 1, 3, 10; Marrin 7; Miranda de Almeida 6c5, 12c1; O’Modhrain 1; Root-Bernstein 12, 13; Solar 8; Thill 5; Tisselli 1; Ox 1; Pasternak 1; Wan 1; Zilberg 1, 2.

### **CONVENING:** Overcoming transdisciplinary thresholds

2. Conferences, workshops, camps. Specific suggestions included “hot” topics, scouting, Environmental Sciences and ecology, STEAM, how to more fully engage the scientist community in SEAD initiatives, complexity art, digital manufacturing, biomedical, boundary fields, and MOOCs.

Author Key: Barnes 1, 3, 4; Batson 1a; Braash 1, 2, 3; Brown 3; Delsaux 6; Jacquemin 7, 14; Marrin 1, 2, 5; Meirelles 1, 3; Ryan 2; Solar 1; Strohecker 15, 18, 19; Tromble 1, 4; Wagoner 4; Williams 3.

### **ENABLING:** Sustaining balanced SEAD relationships

3. Forming safe, productive environments for hybrid individuals and practices. Suggestions included setting up joint appointments in art and science departments, establishing scientist residencies, and expanding artist residencies.

Author key: Blumenthal 2, 3, 4, 5; Cohen 1; Davis 3; Fremantle 2; Garrett 4; Jacquemin 3; Kochhar-Lindgren 2; Kuhn 4, 11; Lapointe 5; Miranda de Almeida 1a1, 1a3, 2a2, 5c4, 6c5, 16d2; Orfescu 1, 3, 4; Pampin 4, 5; Pasternak 2; Presley 4; Quintana 2; Solar 4, 5; Strohecker 14, 21; Pampin 1, 2; Root-Bernstein 16; Ryan 2; Tseng 1; Wan 4.

## **INCLUDING:** Spurring innovation through diversity

4. Communities addressing global issues and local solutions. This cluster includes global communities of practice, global values, and ecological diversity as well as underrepresented groups and rural communities.

Author key: Challa 6, 7, 8, 9; Garrett 1; Hankwitz 3; Jacquemin 2; Kera 3; Kuhn 10; Quintana 4; Root-Bernstein 5; Tatar 1; Thill 4; Tisselli 4, 5; Tseng 1; Wan 1; Williams 3.

## **EMBEDDING:** Public engagement and negotiation

5. Outreach, “citizen science,” dissemination. The importance of public articulation and outreach was perceived as a many-to-many concept. Specific ideas include the equivalent of a “Nobel”-type of prize for SEAD works.

Author key: Batson 2, 3bc; Challa 11; Cohen 2; Emmer 3; Evans 1; Jacquemin 12; Kera 2; Kuhn 10; Miranda de Almeida 1a3, 4a3, 9b3, 13c2, 17d3, 18d4; Parker 4; Pasternak 4; Quintana 1, 3; Root-Bernstein 6; Strohecker 3, 12, 20; Tisselli 2; Tromble 3; Wan 2.

## **SITUATING:** An emerging ecology of creative places

6. “Alt spaces.” Suggested actions in this area included Wet Labs, Skunk Works, Fab Labs, Hacker Spaces, Accelerator/Incubators/drop-in creativity places, as well as spaces within companies.

Author key: Barnes 1, 2, 3, 4, 5, 6; Blumenthal 2; Delsaux 3; Garrett 2; Jacquemin 11, 14; Joy 3; Kera 1, 2; Kochhar-Lindgren 1; Kuhn 2, 4, 8, 9, 11; Miranda de Almeida 7b1; Orfescu 5; Pampin 5; Quintana 1; Parker 1, 2; Pasternak 3; Quintana 1, 4; Strohecker 13.

## **SENSE-MAKING:** Multimodal knowledge and ways of knowing

7. Integrating understandings through the SEAD perspectives. Among the specific topics discussed were projects authors had used to stimulate learning, particularly in K-12 environments. These included perception studies, embodied cognition, how movement (e.g., dance) aids cognitive research, and the use of code to engineer sound projects.

Author key: Batson 1, 2, 3; Fishwick 3; Gresham-Lancaster 1, 2, 3; Kuhn 1, 3, 4; Ryan 1; Wagoner 4, 5; Williams 2.

## **DOCUMENTING:** Recording and transmitting

8. Capturing, publishing, curating, archiving. Many of the transformations underway—such as open-access publishing, multimedia and online publishing, social media, and new forms of scholarship—are accentuated because the SEAD community of practice bridges very different disciplinary cultures.

Author key: Barnes 3.5; Challa 1; Cohen 2; Emmer 1, 3, 4; Essl 2; Evans 1, 2; Ferran 1; Garrett 3; Jacquemin 4, 14; Miranda de Almeida 1a7, 5c4, 15d1, 18d4; Pasternak 5; Presley 3; Strohecker 16, 17; Ryan 1; Solar 2, 3; Tromble 2, 3; Williams 3.

## **LEARNING:** Tapping into the passion and creativity of lifelong curiosity

9. Sharing blended experiences. Learning includes education, lifelong-learning pedagogies, and evaluation methods that integrate the sciences, engineering, arts, and design.

Author key: Batson 3b; Blassnigg 1; Brown 1, 2, 3, 4, 5, 6; Cenkl 1, 2, 3; Challa 5; Davis 5; Evans 3; Fishwick 1; Jacquemin 1, 6; Joy 1, 2, 3, 4, 7; Kuhn 3, 4, 5, 6, 10; Lapointe 2, 4; Marrin 3, 4; Meirelles 2; Parker 6; Pasternak 4; Presley 1, 2, 3, 4; Quintana 6; Root-Bernstein 1, 2, 3, 4, 9, 10, 11, 14, 15; Sarukkai (a) 1, 2, 3; Tatar 1; Wagoner 1, 2, 3; Williams 1, 2, 3.

## **COLLABORATING:** Methodologies working across disciplines and institutions

10. Collaborations between individuals and disciplines. Suggestions in this area come from the ways in which SEAD practice requires individuals from differing disciplinary and organizational backgrounds to think, create, and work together.

Author key: Barnes 4.6; Batson 3; Blassnigg 1, 2, 3, 4, 5; Blumenthal 2; Challa 3; Davis 1, 2, 4; Delsaux 1, 2, 3, 4, 5; Emmer 2; Fishwick 1, 2; Fremantle 1; Garrett 4; Gresham-Lancaster 1, 2, 3; Jacquemin 1, 10–15; Joy 5, 7; Kuhn 7; Lapointe 3; Marrin 6; Nikolov(a) 1; Miranda de Almeida 1b2, 11b5, 14Cc3; O’Modhrain 2, 3; Parker 5; Pampin 3, 4; Parker 3; Siler 1, 2, 3, 4, 5; Solar 6; Strohecker 1, 2, 11; Thill 1, 2, 3, 5; Wan 1.

11. Partnering across organizational boundaries. A wide variety of institutional structures underlies SEAD disciplines and varies internationally. SEAD collaborators pointed to the need for agreements that could benefit SEAD partnerships.

Author key: Jacquemin 1, 5, 8, 9, 13; Joy 5, 6, 7; Kuhn 12; Lapointe 1; Orfescu 2; Pampin 6; Parker 7; Quintana 4, 5; Ryan 2; Solar 7; Strohecker 1, 2, 4, 5, 6, 7, 8, 9, 10, 20; Thill 1, 2, 3; Tseng 1; Wan 3; Williams 3.

## **THRIVING:** SEAD ingredients as essential contributors to healthy communities.

### 12. Ethics and values

### 13. Well-being and joyfulness

Actions in these sections speak of the need for SEAD methodologies to foreground and make overt issues of ethics and values and not defer them to secondary discussions outside of the SEAD community. Authors also mentioned that arts, design, and humanities are important approaches that in themselves contribute to healthy, sustainable societies.

Author key: Challa 2; Davis 7; Marrin 1, 2; Pampin 3, 4, 6; Parker 5; Root-Bernstein 7, 8; Ryan 1, 2; Sarukkai (a) 3; Strohecker 3; Tisselli 2, 3, 4; Wan 2.



## CHAPTER 4

### THE META-ANALYSES: A SYNTHETIC APPROACH

As part of our White Papers methodology, we issued an open call to all the SEAD White Papers authors to contribute to the final report via a “meta-analysis” of the White Papers. The goal was to develop a meta-analytical methodology yielding an overall portrait, or synthesis, of the state of mind of the SEAD community from a multinational perspective.

A stimulus for adding the meta-analyses was that interested parties noted gaps in the White Papers collection, especially in the area of generating sufficient statistics to analyze and distill overarching conclusions about SEAD initiatives. This step reflects a key criterion of the project, namely that the SEAD community of practice be self-critical and self-analytic using the tools and data now available on our own behaviors and practice.

The meta-analysis employed here uses research synthesis and systematic review as well as purely statistical evaluations, but by viewing the 55 White Papers (or a subset of them) as a single text, it is possible to use meta-analysis approaches (e.g., keyword frequency).

Abstracts for the four meta-analyses, by Gabriel Harp, François-Joseph Lapointe, Cristina Miranda de Almeida, and Jonathan Zilberg, are included in Appendix 2; the full documents are posted at <http://wp.me/P2oVig-qa>. The insights provided by these papers have been included in the Suggested Action clusters in Chapter 3.

Some points raised by these authors are worth emphasizing.

1. C. P. Snow’s “two cultures” thesis is again revealed as a flawed conceptual framework. Both Lapointe and Zilberg, using different approaches, conclude that today’s SEAD community of practice demonstrates that Snow’s “two cultures” framing of the situation (1964) is neither accurate nor useful. In a detailed network analysis of 40 of the White Papers, Lapointe demonstrates that the data does not support a “two cultures” description of the

actual research and practice networks; in addition, he highlights the existence of a large cohort of “arts scientists” whose practice bridges the cultures and, accordingly, who cluster in the network analysis. The paper reveals the power of network analysis for the study of intertextual comparisons and exemplifies methods for research using social and textual analytics. Zilberg points out that many of the SEAD White Papers authors problematically assume a “two-cultures” premise and reflect it in their discourse. He argues that this insufficiently questioned premise significantly compromises the SEAD network’s potential. (The title of our report, “Steps to an Ecology of Networked Knowledge and Innovation” is a constructive attempt to shift the paradigm of SEAD discussions beyond a “two cultures” premise.)

2. SEAD practitioners should be cautious about describing the impact of their work on science. In analyzing more than 20 of the White Papers, Zilberg issues a note of caution about the value of SEAD research in enabling new scientific discoveries. He notes that cross-disciplinary work can and does contribute to scientific creativity and science education. But in terms of the most basic and direct criteria, he argues, SEAD cannot yet be seen as a fully transdisciplinary project because it has not been demonstrated that the arts can contribute in a systematic manner to basic science. Nevertheless, it is possible that SEAD-style projects have inspired scientific work. It seems, he concludes, that not only is clarity required about the nature of the disciplinary relations, but perhaps some basic research should be conducted to look into their particular contributions and effects more closely. Nevertheless, it is worth noting that several scientists participating in the study by Strohecker, Malina, and Silk (2012) describe ways in which arts and their work with artistic collaborators have influenced their scientific thinking, discoveries, and inventions.

3. Converting Suggested Actions into process strategies is critical for the success of SEAD initiatives. Harp and Miranda de Almeida provide in-depth alternative analyses of the 260 Suggested Actions in the SEAD White Papers. Harp derives 41 action areas, grouping insights into the domains of people, platforms, and practices. He notes that Tardif and Sternberg (1988) present similar

themes, identifying processes, persons, products, and places as important clusters of focus for creativity research. Miranda de Almeida analyzes from the perspective of Theory of Action; her methodology offers a tridimensional matrix to deal with six different kinds of action, four kinds of stakeholders, and four spheres of integration/collaboration.

The meta-analyses also contribute constructively to the rationale that motivates the overarching Suggested Action that the time is ripe to initiative a “Beyond Productivity II” study and report, aiming to accelerate SEAD agendas. Although generating sufficient statistics was not a goal of the SEAD White Papers initiative, the insights the meta-analyses provide strongly indicate that statistical analysis deserves attention as a Suggested Action for a “Beyond Productivity II” report.

## CHAPTER 5

### CONVERTING IDEAS AND PRACTICES TO CONCERTED ACTION

This effort began with a call to the international community for White Papers addressing opportunities and obstacles in the SEAD community of practice. From the 73 abstracts and 55 White Papers submitted, we received 260 Suggested Actions. Many of the Suggested Actions reflect a broad consensus in several areas; we have found that many areas of concern also appear in the inventory of more than 40 prior reports (see Appendix 3). Others are novel or reflect emerging areas of practice. We hope that stakeholders seeking to accelerate SEAD agendas will find this large community-based study useful.

The draft synthesis of this report was delivered at the conclusion of the SEAD grant and posted online in open access, inviting feedback and comment (feedback on the draft report was collected at <http://wp.me/P2oVig-qF>). The final report is at <http://wp.me/P2oVig-3b>) (Malina 2013). This feedback played a role in the shaping of the final report. In addition, comments have intensified connections among SEAD practitioners, and the type of transdisciplinary explorations that we hoped the report would spark have indeed materialized.

The SEAD community is the inheritor of many decades of development of practices and agendas, and our overall impression is of a dynamic, vibrant, and rapidly growing area of practice. Many opportunities exist for contributing to urgent questions that reflect priorities in our communities. The nature of transdisciplinary collaboration is such that there are many stakeholders who have interests in the success of the SEAD agenda and may be in positions to remove or reduce obstacles. One area in particular that needs attention is the interface with funding agencies and nonprofit organizations.

As indicated in the opening of this report, there has been a sense that it would be useful to stimulate a new national study that would follow on from the 2003 *Beyond Productivity* report. This still seems a desirable goal, one that this White Papers study serves by beginning to map the new landscape.

We would like to thank members of the large international community who have contributed to the SEAD White Papers process and hope that the results will be useful to each individual and organization in their own context.

### **A Call to Action: Is It Time for “Beyond Productivity II”?**

Since 2003, several things have changed that might motivate a new national study in the United States as well as in other countries.

Whereas the focus of *Beyond Productivity* was information technology and creativity, the span of disciplines invested in by SEAD practitioners now ranges well beyond these, from the biological and health sciences to space exploration to nanosciences. New opportunities and obstacles have arisen that were not addressed by the *Beyond Productivity* report. The NSF and NEA workshops over the past three years have brought together very disparate research communities that do not often convene in the same venues.

But it is also clear that there has been an almost explosive growth of the community over the past 10 years, with increasing interest in industrial innovation and economic growth agendas, the establishment of university programs of a wide variety, and the emerging vitality of the maker and hacker communities and other civil society actors.

Collaborative practices are evolving rapidly, promoted in part by online communities but also spurred by a renewed interest by government, industry, and civil society in inter- and transdisciplinary practices. Specific areas of interest are “hard” societal problems such as health care, climate change, and sustainable development. The recent emergence of digital manufacturing based on 3D printing and rapid prototyping, which is now developing momentum in many fields, naturally intersects with the SEAD community of practice.

Networked learning environments were already evident in 2003, but their more recent evolution as online courses, blended learning, MOOCs, and other configurations has accelerated

collaborative learning. Recent developments fuse formal and informal learning and promote expertise-sharing more generally, through crowdsourcing and other methodologies. In addition, “citizen science” has emerged as a focus of innovative development.

The STEM to STEAM movement to increase the role of the arts, design, and humanities in STEM strategies has acquired national visibility in the last three years. How educational communities should respond to the developments in the SEAD community is an open agenda with promising implications for broadening participation in STEM fields. The issues raised cross formal and informal learning, continuing education, and re-training; any study must bridge the silos between the different educational systems and the emerging online systems.

*Beyond Productivity* was carried out in a US context. The SEAD White Papers report reveals that this research community is deeply international in nature, marked by international consortia in arts and humanities that were rare ten or twenty years ago. The issues, problems, and opportunities vary in emphasis across the developed and developing world; SEAD-related work in Africa, South America, and Asia is much more prevalent than was the case in 2003. Especially given the highly collaborative nature of SEAD work, it would be opportune to provoke an international component of a new study to specifically focus on opportunities and obstacles on an international scale.

The 2003 emphasis on “creative IT” reflected the dramatic and rapid dissemination of information technologies into cultural and creative practices. Since that time, developments in the digital humanities have brought new terrains of collaborative practice into focus. One of the NSF/NEA workshops was also cosponsored by the National Endowment for the Humanities. The SEAD scope intentionally sought to cover the range of disciplines in all forms of the arts and design, but also the humanities—and this appears to be a new area of emerging opportunities.

We have titled our SEAD White Papers report “Steps to an Ecology of Networked Knowledge and Innovation: Enabling



New Forms of Collaboration among Sciences, Engineering, Arts, and Design.” In 2003 and even before, it was evident that the traditional “triple helix” of innovation that linked government, industry, and academia was no longer the operative framework for the way that research and creation were being translated for societal uses. In Europe, the Creative Industries movement already captured this change to an ecology of networked actors; in the United States, Richard Florida and others have popularized the concept of the Creative Class, while *Beyond Productivity* addressed many of the opportunities and needs in creative neighborhoods and communities; and in Brazil, digital culture programs have created new frameworks that have propelled that country into the forefront of SEAD activity.

In our introduction above, we expanded upon an ecological metaphor to foreground a shift from linear, hierarchical structures of knowledge creation and sharing to that of a networked structure. Already anticipated by Cathy Davidson and David Goldberg in their report, “The Future of Learning Institutions in the Digital Age” (2009), this shift also has implications for organizational structures and funding as well as service. This means, for instance, that a national study must engage the different agencies that are stakeholders in the success of SEAD practice. While *Beyond Productivity* was sponsored by the Computer Science and Telecommunications Board of the US National Research Council, a new study would necessarily engage equally the arts, design, and humanities.

It seems to us important that all the actors in this emerging culture of networked knowledge make their voices heard in identifying opportunities and obstacles for SEAD perspectives and work. Their input would build on an impressive body of work represented in reports by many industry, government, and civil actors who have begun identifying strategies. Reports are no substitute for action, but the periodic refreshing of the analysis and the convening of the actors are essential networked knowledge methodologies.

In some disciplines, such as the US astronomy research community, the NRC conducts “decadal surveys” to identify and

reprioritize the continually evolving research and programmatic context every ten years. The SEAD White Papers report used an open call to the international community, and we were overwhelmed by the response—with more than 200 participants, 55 detailed White Papers, and four in-depth meta-analyses. Our “open access” approach also provided a high degree of transparency. We can imagine using various crowdsourcing techniques in a “Beyond Productivity II” study that would allow broad participation and a diversity of conclusions.

In conclusion, the SEAD White Papers Study coauthors suggest to the SEAD network that discussions be held with interested parties on the possibility of funding a “Beyond Productivity II” report, to be carried out some 15 years after the work on the 2003 report was initiated. New opportunities and obstacles exist, and a new report would provide a timely analysis to the whole range of stakeholders who have a vested interest in enabling new forms of collaboration among the sciences, engineering, arts, and design communities. With a focus on how SEAD approaches can be applied to the critical and difficult challenges of our times, such a report would also provide an impetus to accelerate the sources of innovation and economic development that are crucial to the coming decades.

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## APPENDIX 1

### LINKS TO ABSTRACTS AND WHITE PAPERS

The following abstracts and White Papers were submitted and posted on the SEAD website (<http://seadnetwork.wordpress.com/white-paper-abstracts/final-white-papers/>). Citations contain links to the abstract and the full article, if the abstract was expanded upon. In the cases where the title was changed for the full article, two citations are provided.

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## **APPENDIX 2**

### **META-ANALYSIS ABSTRACTS**

The full meta-analyses can be accessed at <http://wp.me/P2oVig-qa>.

#### **SEAD Themes and Insights Meta-Analysis: From Conflict to Coherence**

*Gabriel Harp*

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The following survey of insights was developed for the Network for Sciences, Engineering, Arts, and Design (SEAD) White Papers project.

To build on the emerging themes presented in the White Papers, this meta-analysis groups insights into the broad domains of people, platforms, and practices. Similar themes are presented by Tardif and Sternberg (1988) who identified processes, persons, products, and places as important clusters from a corpus of research on creativity. Similarly, in the emerging literature of social practice and innovation, Shove, Pantzar, and Watson (2012) have gone a step further, describing in detail how the dynamic interactions of meaning, competencies, and materials drive changes in the consumption and use-patterns of everyday life. Both frameworks recognize that the critical infrastructure of creativity, diversity, and coherence is driven by the ongoing churn between people's thoughts, practices, and the materiality of our environment. More effort and attention should be directed at identifying concrete objectives and impacts for cross-domain research and creative work.

When people and teams that are exploring cross-disciplinary research develop statements about the broader impact of their work, as NSF proposals require, they can call attention to and reinforce the societal benefits they offer, providing a goal-driven mechanism to communicate the benefit of research to society.

## **A SEAD Network Analysis of White Papers**

*François-Joseph Lapointe*

Department of Biological Sciences, Université de Montréal

Much as been said and written about C. P. Snow's two-culture paradigm (1963) separating the world between artists (humanists) and scientists. On one side of this debate are those who accept and celebrate this cultural art/science divide. On the other side are those who reject it altogether to promote a better integration of arts/science practices. The SEAD White Papers aim to identify the roadblocks preventing transdisciplinary (or transcultural) research. As such, they present an insider's view of the collaborative process involving artists, designers, scientists, and engineers working alongside each other on common projects. More importantly, these papers offer a representative sample to test the two-culture model by examining in detail the opinions expressed therein. This meta-analysis utilizes an "objective" network analysis of the content of the White Papers; in other words, it allows the data to speak for itself. If it is true that artists and scientists think differently, the papers authored by artists and scientists should fall in different clusters in the network, with papers co-authored by both artists and scientists falling in between. This approach tests the hypothesis that the papers submitted by artists and scientists are significantly disconnected in the corresponding graph, as predicted by the art/science separation. Rejecting this hypothesis will provide support for the alternative arts/science integration. The discussion section will then present an interpretation of the results, with personal comments.

## **A Meta-Analysis of SEAD White Papers with a Focus on Research and Creation**

*Cristina Miranda de Almeida*

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This meta-analysis applies the perspective of Theory of Action to 10 White Papers selected for presentation at a session of the

XVIII ISA World Congress of Sociology that addressed issues of transdisciplinarity among science, engineering, arts, and design. It offers a tridimensional matrix to deal with six kinds of transdisciplinary actions: increase of resources; support networking; education of researchers; supporting research; diffusion and sensitization; and creation of interaction structure. These actions are situated according to four stakeholders' scales: individuals, communities, public institutions, and private institutions. These are in turn articulated around four scales of interaction regarding opportunities and obstacles: (1) face-to-face interactions (FFI), such as linguistic opportunities and problems, cross-communications misunderstandings, emotions and insights, etc.; (2) transdisciplinary power synergies, struggles, and competitions such as those that belong to authority and power elites inside each discipline that form interest groups (IG); (3) institutional educational and research structures (ERS) that are discipline-based and can be seen as structures for new opportunities or threats to any kind of transdisciplinary action; (4) social paradigms that are common in public political-administrative systems (PPAS) of funding at different levels, whether national, regional, European, or international, that are not adapted to transdisciplinary action. Opportunities and obstacles for action will be identified according to the following kinds of action, stakeholders, and spheres of integration.

## **A SEAD White Papers Working Group Meta-Analysis**

*Jonathan Zilberg*

Associate Research Scholar, University of Illinois at Urbana-Champaign;  
Research Associate, Department of Transtechnology, University of Plymouth

This meta-analysis comments on a subset of the White Papers that relates to sound/music, dance, pedagogy, thinking with things, sci-art projects and common language. It critiques the papers in terms of the way in which they respond to and rely on the underlying dominance of C. P. Snow's popular notion of two cultures (1963), taking this unexamined thesis as an article of faith dividing the worlds of art and science. Nowhere in any of these papers is the thesis and the history of the concept, or Snow's

simplistic notion of culture, adequately or even rudimentarily addressed.

This meta-analysis emphasizes two points: (1) This debate over the necessity of bridging work in science and culture was also a subject of fundamental importance to scientists, anthropologists, and art historians participating in the National Science Foundation (NSF) analysis of the problem in the 1950s and 1960s. (2) Revisiting Leavis's (1962) and Yudkin's (1962) critiques of Snow and that NSF history, it proposes that White Papers projects should carefully consider the emerging critical evaluations of art-sci projects such as those at the Wellcome Institute in the United Kingdom and the Xerox PARC project in the United States. In doing so, they would avoid making the mistake of justifying funding on the basis that art can contribute to basic science without providing evidence. Instead, what all these papers do document is how SEAD can advance science education, the public image of science, and the creative impulse and rigor across the disciplines that bind them.

## APPENDIX 3

### COMPILATION OF PRIOR REPORTS

Below is a selected bibliography comprised of third-party reports compiled by SEAD researchers. Reports that make recommendations in the SEAD context can be found at <http://SEADnetwork.wordpress.com/reports/>.

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## **APPENDIX 4**

### **DEMOGRAPHICS**

This data represents demographic information about the more than 150 individuals who participated in the SEAD White Papers as part of the Steering Committee, and as Coordinators, Authors, or Advisors.

The gender distribution is balanced, with 49 percent female and 51 percent male participants.

There is a predominance of participants in academic careers, with 65 percent in academic and 35 percent in nonacademic positions (business, nonprofit, government, self-employed).

We listed participants by degrees earned and practice area, divided into three areas: SE (Science and Engineering), AD (Art and Design, including Humanities and Social Sciences), and Hybrid, for people with degrees in SE and AD, or degrees in one area and practice in the other. A majority of 64 percent is in the AD area, followed by 20 percent in Hybrid and 16 percent in SE.

The geographic distribution shows a predominance of participants in the northern hemisphere, with 55 percent of participants from North America, 27 percent from Europe, 7 percent from Asia, 6 percent from South America, 4 percent from Oceania (Australia), and 1 percent from Africa. There are representatives from 24 countries. The United States and United Kingdom account for approximately 75 percent of all participants. Australia, Canada, Netherlands, and Brazil follow with approximately 10 percent combined.



### GENDER

- Male: 51%
- Female: 49%



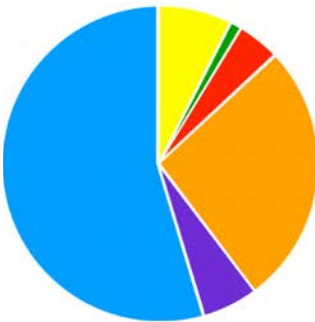
### CAREER

- Academic: 65%
- Nonacademic: 35%



### AREA OF PRACTICE

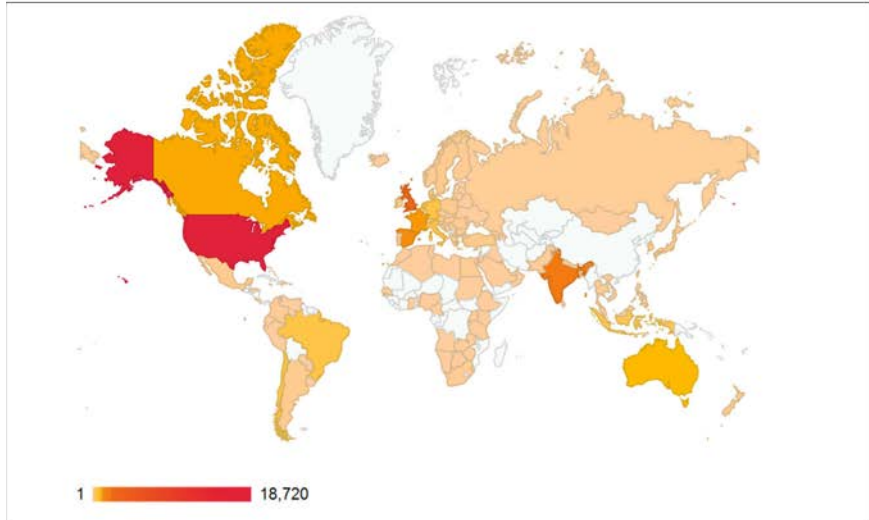
- AD (Art and Design): 64%
- Hybrid: 20%
- SE (Science and Engineering): 16%



### GEOGRAPHIC DISTRIBUTION

- Africa: 1%
- Asia: 7%
- Oceania: 4%
- Europe: 27%
- North America: 55%
- South America: 6%

Top SEAD network White Papers website views by country for all days ending 7/9/2013 (summarized)



Country	Views	Country	Views
United States	18,720	Sweden	82
United Kingdom	2,493	Argentina	82
India	1,939	Mexico	81
Spain	1,111	New Zealand	77
France	1,098	Portugal	68
Canada	950	Thailand	67
Australia	862	Norway	66
Hong Kong	821	Hungary	66
Germany	472	Romania	59
Brazil	472	Czech Republic	56
Italy	443	Finland	55
Chile	424	South Africa	51
Netherlands	410	Colombia	48
Indonesia	383	Bulgaria	45
Denmark	196	Israel	42
Singapore	153	Philippines	42
Belgium	135	Croatia	29
Switzerland	122	Egypt	29
Taiwan	116	Russian Federation	26
Ireland	112	Malaysia	25
Turkey	111	Pakistan	18
Austria	103	United Arab Emirates	18
Republic of Korea	90	Kenya	16
Poland	90	Saudi Arabia	15
Greece	87	Serbia	14
Slovenia	83	Cyprus	14
Japan	82	Costa Rica	11