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INTRODUCTION

The workshop Bridging Stem to Steam: Building New Frameworks for Art/Science Pedagogy, gathered leading thinkers from differing fields to share their insights, discover connections and explore potential collaborations among art and design, and sciences in support of interdisciplinary STEAM learning, research and pedagogy. This report outlines the activities, findings, outreach activities and recommendations stemming from the workshop.

WORKSHOP ACTIVITIES

Sponsored by the National Science Foundation (NSF), Bridging STEM to STEAM: Developing New Frameworks for Art-Science-Design Pedagogy explored ways educators and policymakers could bridge the gap between art and science. Specifically, the goal of this gathering of minds was to develop strategies to enhance Science, Technology, Engineering, and Math (STEM) education by integrating art and design—thereby transforming STEM into STEAM and promoting intellectual and creative possibilities in the process.

The two-day workshop brought together 60 leaders from the fields of science, creative IT, engineering, art and design, mathematics and education research to strategize about innovative ways for these fields to interact, and new teaching approaches to creative problem solving. RISD educators and Principal Investigators (PI) Christopher Rose and Brian K. Smith devised and organized the workshop, and half a dozen other key RISD educators participated in the series of provocative and inspiring discussions. Participants visited the RISD Nature Lab and Museum, incorporating various modes of knowledge building encounters and collectively moving through the different kinds of learning spaces available on campus.

In their presentations and discussions, participants described projects that successfully integrate art and science. For example, Michael Benson, a photographer and illustrator at Kinetikon Pictures showcased about his solar system photography and Jonathan Harris, cocreator of We Feel Fine, illustrated how he uses art and design in the form of information visualization to reveal the secrets and human empathy hidden in datasets. An installation in London called The Breathing City [cross-disciplinary project], sponsored by the Royal Society of Science, showed links between data visualization in complex systems and public engagement with science as presented by Holger Zschenderlein. [See Appendices A & B for descriptions of workshop presentations / activities, and graphical mapping of conversations].

MAJOR FINDINGS

Knowledge Building by Design

The STEM to STEAM workshop effectively demonstrated the principles around which it was designed
i.e., the use of knowledge building strategies to generate space for creative response through the thoughtful arrangement of the experiences of participants, which has proven effective in other cross-disciplinary settings (Zschenderlein & Rose, 2009). Knowledge building requires negotiation of preconceived notions or perceptions (Baillie & Rose, 2004). The sharing of this activity increases critical awareness; both of knowledge structures themselves and an improved critical relationship with experience. In a pedagogical sense this is significant because it is effective both within and across specialist disciplines, and in introducing ‘how science works’ to educated but nonspecialist audiences. Creating spaces and events like STEM to STEAM is an effective way to promote knowledge negotiation between disciplines, and in addressing public engagement in science. Similarly, the STEM to STEAM workshop demonstrated the ‘creation of spaces for learning’ rather than telling participants what they would learn, as happens in more traditionally designed workshops, according to PI Chris Rose.

The workshop was unique in its participatory nature. Participants from varied disciplines were situated in learning spaces together in small groups in a process devised to bring out perceptions in the present moment rather than by the reporting of an established canon of knowledge. In spaces such as the Nature Lab and Museum, participants built knowledge together by taking part in negotiated learning activities which emphasized discussion and agreement of the options available when observation, organization and prioritization are at play. Then participants moved to the next activity in a different learning space. At the end of the activities, all participants came back together to share their stories of what they had perceived and what it prompted in them in their own work. In carefully designing the cognitive activities in such a way, says Rose, the process of learning was slowed down, allowing participants to avoid jumping to assumptions based on preconceived notions or perceptions when interpreting information; rather the process enabled a critical appreciation of the development of knowledge. Thus it was this ‘development’ that became the subject of the workshops, and not any particular instance or vehicle used for the purpose.

Finally, transdisciplinary work often fails because we are comfortable in our own disciplinary niches. The wide range of disciplines represented by participants, and the spaces provided through the design of this workshop allowed people to interact outside their niches. The makeup and design of the workshop provided truly transdisciplinary spaces for discovery and knowledge development, and for breaking down some of the barriers that usually prevent mutual understanding between disciplines (Baillie & Rose, 2004). Participants engaged in exploring ways to develop strategies to better facilitate deep and meaningful exchange between the domains of arts and design, and sciences.

In sum, the design of the workshop i.e. through application of knowledge building strategies, the participatory and cross-disciplinary nature of the event, and participants’ resultant experiences led to the articulation of the key findings that emerged from the workshop. These are described in more detail below.

Reinvigorating STEM Education through STEAM

Among the key points emerging from the workshop is a consensus that a significant crisis exists in STEM education, with the greatest challenges being around the formal education system and accessibility to the sciences, according to Shirley Malcolm, head of the Directorate for Education and Human Resources Programs of the American Association for the Advancement of Science. Moreover, there is a lack of understanding of what it means to sustain learning opportunities notes Rose.

Deep, sustained, varied learning is key to STEM education. For STEM education to be successful, a fundamental shift is needed in how we think about learning. The STEAM agenda is not about adding
the Arts to STEM; rather, “it’s more about fundamentally changing education to incorporate the experimentation and exploration that is at the heart of effective education” notes Margaret Honey, CEO of the New York Hall of Science. Participants agreed that the STEAM agenda should be about deep, sustained, powerful engagement as a way of learning. Exploration, experimentation and problemsolving are all important features of high-quality learning according to Honey. In order to take hold, learning needs to be varied and textured suggests Marina McDougall, arts project director at the Exploratorium of San Francisco. At the same time, she says, learning should encompass an escalation from data to information to wisdom, while developing in learners a sense of agency.

Likewise, McDougall recommends an emphasis on holism in learning is needed, as well as recognition of the myriad ways of seeing, exploring and knowing among learners. The world comes to us whole and we explore it from many different perspectives e.g. cultural, economic, historical, or as part of a larger system: Pedagogy that recognizes individuals’ different ways of seeing and knowing is a key element of effective education. A core feature of this pedagogy is inquiry or inquiry-based learning i.e. minds-on, hands-on, active learning says Malcolm. This kind of learning helps learners to discover their own curiosity agrees McDougall.

Good teaching and learning is also about good observation. “The best schools allow kids to get obsessed, to dive deep into something” – these schools focus on learning deeply, and the process of how learners keep learning, and continue to grow, says Honey. Likewise, a philosophy of “not teaching in absolutes” should be encouraged suggests Richard Wurman, chairman and creative director of TEDMED; rather we should create spaces for exploration, inquiry and change.

Other key elements of effective education suggested by Malcolm include effective curriculum and performance assessment, which means identifying what authentic assessment looks like, and how this is shared with parents. It also involves efforts to move policy discussions away from how education outcomes are assessed toward focusing on what should be learned. As Honey notes: The most successful models of learning happen when learning is not legislated. “Trust is a critical ingredient in learning; the policy environment is trust but verify.”

Finally, accessibility is a critical issue in STEM Education, says Honey. We need to explore ways to ensure the broadest access for engagement in the sciences, creating multiple pathways to knowledge and learning. This means examining how we use opportunities to invent, create and open learning for students, and going beyond engaging children in science through textbooks. Make, play, and design are more effective as strategies to engage the formal education system, and promote learning in STEM notes Honey. An important element of this may be encouraging teachers to see their objective as helping students build knowledge about a particular subject in ways that are meaningful to them (Baillie & Rose, 2004).

Mathematics is at the Heart of Learning

Mathematics has a central role to play in knowledge building, in arts-science collaboration and in transdisciplinary work, posits Rose. The issue is not math itself but rather that people cannot easily access the relevant concepts of math, or have different ways of accessing it. Math is the common language across art and design and the sciences, and in the nature of cognitive processes themselves. In order for sustained transdisciplinary collaboration to work, the mathematical dimension must be addressed and techniques found to connect to the multiple forms of intelligence to be found in a broad set of collaborators with appropriate mathematical concepts, depictions and principles.
Surface and Deep Knowledge

Different types of people are in the realm of developing knowledge, and have specialized bodies of knowledge and expertise. Surface knowledge is important because it affords a point of entry for a wide range of individuals. Deep knowledge is necessary in order to create meaningful change: both forms of knowledge and their effective mutual connections need to be acknowledged in formats such as this workshop, in order for transdisciplinary collaboration to be successful.

Increasingly, the world calls for fluency across disciplines as well as disciplinary expertise yet there is a crisis of overspecialization in knowledge fields. This leads to communication challenges both within scientific disciplines, across disciplines, and with external audiences. Other challenges include “not being able to see the big picture” and the challenges of engaging the public in science (Rose, 2010, p. 18).

Much transdisciplinary research and collaboration often fails due to a “guild mentality” i.e. groups are comfortable in their own niches, do not use the same language and often have different funding structures, says Johannes Goebel, director of the Experimental Media and Performing Arts Center at the Rensselaer Polytechnic Institute. Other differences exist that may impede collaboration: STEM’s intention was described as goal-oriented versus that of art, which is process-oriented. Artists tend to possess “peripheral vision” versus “aiming at a target”, which much scientific work naturally focuses upon. Physical barriers also impede successful transdisciplinary collaborations: Art and sciences lack places where they can come together, and disciplines are physically and geographically separated posits Holger Zschenderlein of the University of Brighton, UK.

In this context, there is a potentially important role for visual artists and visual thinkers to improve communications between the disciplines and outwardly to general audiences. “Specialized skills in visual thinking, virtual and physical media, and the critical engagement with cognitive and associative languages and their connections with all forms of human experience” are found in the art and design domains, and can aid in this process of sharing in the insights of science (Rose, 2010, p. 18). Similarly, the use of multiple intelligences (i.e., the sensory, haptic, performative and perceptual) are all present in art and design practices, techniques of which can be used to address, and assist others to address, some of the challenges outlined above. They may be used to create multi-dimensional approaches or pathways to knowledge. Artworks can combine powerful imagery, unspecified connections to experience and knowledge, and aspects of intentional ambiguity. It is this ambiguity that affords an opportunity for knowledge building with those people drawn to or engaged by the artworks. Holger Zschenderlein illustrated this principle, for example, in his presentation of the Royal Society of Science installation relating to climate and energy and incorporated in ‘STEM to STEAM’ both as one of the keynote presentations and in the organization of the event.

More opportunities are also opening up for artists, designers and performative specialists to work in STEM due in part to the wide availability of technology, according to Pamela Jennings, program manager at NSF. This is especially true in terms of the convergence of visual representation of complex topics, cross-platform editing and interactions that are intrinsically shareable and open to critique in cross discipline contexts.

Finding Common Ground

Currently, a bifurcated world exists between art and science worldviews, viewed by participants in the workshop as somewhat artificial given that more similarities than differences were noted between the domains, says Malcolm. Some of the similarities noted include (Bridging STEM to STEAM, 2011):
Both artists and scientists are confronted with chaos, and try to make meaning of it by seeking patterns within randomness—in patterns they are looking to discern abstracted indications of possible meaning.

The work of artists and scientists is characterized as the ability to “make the invisible visible,” or “to make the unknown, known,” and to see patterns and make associations. Both groups ask excellent questions, and possess great curiosity and drive.

Artists and scientists “bring emotion, passion, and play to their inquiry”.

Both groups have audiences and want to communicate effectively with their audiences.

Moments of inspiration are common among all disciplines, and should be embraced.

Reconnecting the worlds of art and sciences may inspire creativity and innovation in science education and communication, and contribute to addressing world challenges. Creativity, after all, has been defined as “shared imagination”, and is multidisciplinary and applies equally to any discipline (Dewulf and Baillie, 1999). And when science and art come together, notes RISD graduate student Sara Raffo, they reveal “freedom, truth and joy in the world around us.”

Nonetheless, a number of key issues emerged in relation to the STEAM movement. Participants expressed concern about the importance of arts and design disciplines to maintain their integrity as independently valid disciplines. In this context, STEAM should ‘resist the temptation in the current climate to serve as an addition to enhance science’s public engagement in exchange for joining a more generous funding stream” (CRD), 2011, p. 22). However, if trans-disciplinary collaboration is “genuine and critical,” it has the “potential for mutually creative and innovative models to emerge, which can lead to insights that could not otherwise be achieved” (Center for Research & Development, 2011, p. 22).

**RECOMMENDATIONS FOR STEAM LEARNING, RESEARCH AND COLLABORATION**

A number of strategies and recommendations emerged from the workshop for STEAM learning, research and collaboration.

**Future Areas of Research**

To support the development of new frameworks for Art/Science pedagogies, educators need to develop a greater understanding into the processes of how we learn, identify the gaps in knowledge, and explore ways to bring together arts and science pathways in education. One proposal is a study of successful learning models for best practices in effective STEM/STEAM education and collaborations, in either academic or industry settings. Many examples of transdisciplinary research and projects already exist, and many places already effectively gather these kinds of people—Silicon Valley, PIXAR and others—these spaces can be explored as well as those in academic settings.

Second, the potentials and symmetries that happen across STEM and the Humanities should be investigated.

A third area of research could study the kinds of people that embody STEAM, for example, by examining their educational or professional paths, and exploring what this insight might mean for educational programming. Such a study could help inform educational policy, approaches and programs.
**Pedagogical Innovations**

Pedagogical innovation can be realized through encouraging and facilitating unorthodox learning methods and strategies that respond to a wide range of learners. This accommodation will allow different pathways to knowledge in STEM/STEAM. Key to this is encouraging educators to think *experience design* versus *curriculum design*.

It also means pushing institutions forward on STEAM education, especially in finding ways for art and science to intersect. Participants supported a move away from legislating what learners have to know and promoting too many ideas simultaneously. Rather, the emphasis should be on determining core areas of knowledge and competencies required by STEM / STEAM learners, and creating and allowing different paths to gain knowledge. Building greater trust in education is critical as well. “Trust is a critical ingredient in learning” but “the policy environment is trust but verify.”

**Creating Spaces for Transdisciplinary Work**

Interdisciplinary research and collaboration of the arts and sciences can be further facilitated through the creation of physical, inclusive spaces where artists and scientists can come together to experiment, explore, and develop insights. One technique is through structures and spaces where “not knowing” can take place. In these spaces, we should ask “what can these things be rather than recognize them for what they’ve been,” suggests Tom Ainsworth, a graduate student in design at the University of Brighton, UK.

Others suggested a need for greater cross-disciplinary learning to avoid the “guild mentality” that drives the disciplines apart. As such, educators should explore ways to reconnect the arts and sciences and engender interdisciplinary learning. One participant recommended that we break down the mind / body dualism, and adopt a new and interesting metaphor for STEAM: the concept of “thinkering” = thinking + tinkering.

**Dialogue Between The Arts and Sciences**

Finding ways and means for continuing the dialogue between Art / Design and STEM and inquiry into the myriad of ways they can interact should be a priority.

Ongoing dialogue will assist those from different disciplines in exploring issues and opportunities related to bridging STEM to STEAM, engaging in spaces that foster ideas about what might be STEAM, and to find ways to bring art, design and scientific communities together and make them stronger. Equally important is fostering diplomacy between the disciplines to facilitate a deeper understanding of learnings from different disciplines and to find a common language. ‘Artist in Residence’ and ‘Scientist in Residence’ schemes assist as they provide both the ambient and specific opportunities for awareness-building. It’s important that the dialogue across disciplines be respectful, reflective and on an equal footing, and that it foster understanding of different disciplines and their interrelatedness (CRD, 2011).

**OUTREACH AND LEARNING ACTIVITIES**

**Public Engagement**

RISD has taken an active role in engaging the world in conversations about the concept of STEM + Art
STEAM, and the role the Arts can play in making science more visible and humanizing technology. This workshop is one of many STEAM initiatives carried out over the last few years. Others include: 1) conferences such as Making Science Visible, also devised by PI Christopher Rose; 2) regular presentations by President John Maeda and RISD faculty in varied and numerous forums on STEAM; and 3) NSF EPSCOR activities for developing ongoing co-taught cross-disciplinary classes of a research nature; promoting public engagement with science including exhibits, interactive public encounters, information and data visualization, symposia, publications and others.

Together, these public engagement activities have helped move the STEAM idea into the mainstream, and support a greater understanding of basic principles of STEAM. STEAM is now being established as a concept backed up by methodologies and defined objectives. People are curious about STEAM and what it means or might mean in terms of learning and pedagogy. Many are asking the question, “What is STEAM and why do we care about the Arts?”

Trans-disciplinary Experiences for Art and Design Learners
RISD is expanding opportunities for new educational experiences for artists and designers that are based on STEAM principles, and informed by the workshop proceedings. Examples include:

“Creative Insight: Preparation for Effective Arts / Design / Science collaboration”, a seminar course devised by PI Christopher Rose and offered for the first time by Academic Affairs at RISD as a graduate study elective in Spring 2011. The course was informed by content derived from ‘STEM to STEAM’ together with keynote material and observations from that event.

PI Christopher Rose continues to expand the graduate research studentship scheme at RISD in conjunction with the ongoing RI-EPSCoR program. This provides for assistantship opportunities for graduate students from the different disciplines of design and arts playing a significant role in the development of different types of interdisciplinary working and building experience in this area as an ongoing program.

The RISD Museum Gallery program with visiting artists in 2011-2012 features public conversations chaired by PI Christopher Rose continuing with an arts/science theme and featuring notable practitioners.

The format of and content from ‘STEM to STEAM’ was presented to a visiting delegation from AAAS in June 2011. The delegation was part of a review of the RI-EPSCoR project and its practical rollout, which was informed in part by the STEAM workshop proceedings.

In conjunction with Graduate Studies Dean Brian Goldberg, the graduate student “transdisciplinary” experience is being enriched through assistantship opportunities with science labs, research classes and new cross-discipline courses under continuous development through EPSCoR.

Publications & Digital Engagement
Website: RISD produced an interactive website for the workshop to promote activities related to STEM to STEAM initiatives (stemtosteam.org). The event was also highlighted on EXPSpace, a participatory research platform to connect artists, designers and scientists to shared research interests, ongoing work, and opportunities for collaboration. ([HYPERLINK “http://expspace.risd.edu/?research=stem-to-steam-workshop”](http://expspace.risd.edu/?research=stem-to-steam-workshop))

STEM to STEAM archive: [HYPERLINK “http://stemtosteam.org/archive/”](http://stemtosteam.org/archive/)

**In the News** (sample coverage):


Providence Forum Explores the Intersection of Art and Science, The Providence Journal by Linda Borg, September 27, 2011


**In the Blogosphere** (samples):

John Maeda, President, RISD: http://our.risd.edu/2011/02/02/stem-to-steam-at-risd/


Tonia Hsieh, Assistant Professor, Department of Biology, Temple University: http://templebiomimetics.wordpress.com/category/stem-steam/


**Contributions Within and To Other Disciplines**

Findings from the RISD-NSF STEM to STEAM workshop continue to inform the long term RI-EPSCoR scheme for educational and research institutions in Rhode Island and other national and international Arts/Science/Design collaborations that feature in RISD’s activities. Pedagogical developments that are core to effective interdisciplinary and interinstitutional working are informing the Strategic Plan for RISD.
CONTRIBUTIONS TO RESOURCES FOR RESEARCH AND EDUCATION

Concepts articulated by participants in STEM to STEAM are referenced in the developing program of interdisciplinary co-taught classes within the network of institutions in RIEPSCoR. These classes are supported in each case by an appropriate graduate student research assistantship for each interdisciplinary class. A typical student assistant will have either a science-related undergraduate degree working in conjunction with their arts/design graduate program of study, or a specific interest in such topics as data visualization, interaction design, and pedagogical issues connected with interdisciplinary working (i.e. an interest in teaching).

STEM to STEAM mapped out a family of related topics and directions that are used in supporting this innovative development in the student experience. Plans for expansion are underway in terms of science/art research assistantships which, when experiences are pooled, will continue to inform student and faculty planning in this domain.

CONTRIBUTIONS BEYOND SCIENCE AND ENGINEERING

How have results from your project contributed to the public welfare beyond science and engineering (e.g., by inspiring commercialized technology or informing regulatory policy)? Please enter or update as appropriate.
REFERENCES


APPENDIX A:

BRIDGING STEM TO STEAM: WORKSHOP SUMMARY

CO-SPONSORED BY RHODE ISLAND SCHOOL OF DESIGN (RISD)
AND THE NATIONAL SCIENCE FOUNDATION (NSF)

JANUARY 20–21, 2011
RHODE ISLAND SCHOOL OF DESIGN
DAY 1: EXPLORATION

“The Unknown is the Best Place” — John Maeda

9:15 AM

OPENING DISCUSSION: PARTICIPANTS: RISD PRESIDENT JOHN MAEDA, PROVOST JESSIE SHEFRIN, PAMELA JENNINGS (NSF) AND EVENT PARTICIPANTS

Day 1 of the workshop began with an invitation to participants from RISD President John Maeda to enter into a “public fishbowl” or circle to begin the workshop’s exploration. He then asked each participant to note their professional affiliation and how they came to be here, and to give their best example of a gathering in which they had participated that led to interesting results.

John Jay of Wieden + Kennedy, said his creative company connects with youth all over the world, and his interest in exploring the culture of youth and creativity propelled him to participate in the workshop. “Creativity is very much a part of science,” said John.

Science is relevant “to just about everything” but how can you connect arts and STEM, asked Marjory Blumenthal, Associate Provost, Academic of Georgetown University. There is a need to push institutions forward on STEM education, and to find ways for art and science to intersect, she said.

Sarah Ganz, Director of Education RISD Museum of Art emphasized the need for more interdisciplinary learning, and the importance of learning from the past as well.

Pamela Jennnings, Program Director, CISE Information and Intelligent Systems Division, CreativeIT and HCC Programs of the National Science Foundation, said she had been involved previously in a Creative IT program that united creative cognition, information technology, science and other disciplines. She wished to continue the dialogue and discourse about the interaction of disciplines, and was excited about learning from other participants.

“How we learn” and “how we dream” are of great interest, said RISD Provost Jessie Shefrin “and how do we get from STEM to STEAM?” She observed the importance of understanding these processes as well as the gaps in knowledge, and exploring ways to bring together these pathways in education.

The UK Royal College of Art is already a “very STEMMy kind of place” remarked Rector Paul Thompson, where designers work everyday with synthetic biologists and medical researchers. This integration will be greatly affected, he noted, by a “radical shakeup in UK universities” currently underway, in which all arts and humanities funding is to be cut for education.

9:45 AM

FOUR CAPSULE PRESENTATIONS BRIEFLY HIGHLIGHTED THE “IN-BETWEEN SPACES” OCCUPIED BY MANY ARTISTS, DESIGNERS AND SCIENTISTS.

Capsule 1: Nicholas Jainschigg, Associate Professor of Illustration at RISD illustrated how the worlds of art and science intersect through his unique creations in science fiction and “fact” illustration, including detailed images of trilobites.
Capsule 2: A cross-disciplinary research project on handheld devices for rheumatoid arthritis brings designer Tom Ainsworth, a graduate student at the University of Brighton United Kingdom into close contact with rheumatologists and patients, whose “lived experience of the condition” informs his designs.

Capsule 3: Joy Ko, Assistant Professor of Mathematics at Brown University, has spent the last three years working in the field of architecture, and embodies the concept of STEM to STEAM. Successful STEAM collaborations require “intuition and instinct grounded in good practice,” she observed. “Think big, take small doable steps, [and] develop strategic process along the way.”

Capsule 4: “Holism is a way of knowing,” explained Marina McDougall, Arts Project Director at the Exploratorium in San Francisco. “The world comes to us whole – we explore it from many different perspectives.” The many ways of “knowing a tree”, for example, range from examining its leaves under a microscope and composing a haiku poem about it, to noting the kinds of birds who build their nests in its branches or by simply climbing it. No matter the perspective—be it cultural, economic, historical, or as part of a larger system—learning and education should be about helping others to discover their own curiosity. “Learning needs to be varied and textured to take hold,” said Ms. McDougall.

10:30 AM MINI-KEYNOTE: SHIRLEY M. MALCOLM, DIRECTOR, EDUCATION AND HUMAN RESOURCES, AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE (AAAS), AND MARGARET HONEY, PRESIDENT AND CEO, NEW YORK HALL OF SCIENCE IN CONVERSATION

Brian Smith, RISD’s Dean of Continuing Education and Co-Principal Investigator of the workshop, opened the conversation by suggesting that perhaps the difference between STEM to STEAM is artificial.

Shirley Malcolm of AAAS agreed. Leonardo DaVinci was a renowned engineer, architect, scientist and a painter. “Why choose just one? asked Ms Malcolm in her remarks to participants of the STEM to STEAM workshop. “Why was this artificial bifurcation made [between the arts and sciences] and how can we reconnect it?” She expressed concern about how to support cross-disciplinary learning, and to avoid the “guild mentality” that drives the disciplines apart. The best scientists already do this: For example, Stephen Hawkings has said that he turns complex mathematical formulas into pictures in his mind in order to hold the ideas, she noted.

Margaret Honey, New York Hall of Science, reflected on the STEAM agenda from the point of view of learning. “STEAM shouldn’t be thought of as an additive agenda,” she said. “It’s not about adding an arts agenda. It’s more about fundamentally changing education to incorporate the experimentation and exploration that is at the heart of effective education.” It’s “about shifting how we think about learning … deep, powerful, sustained engagement is what the STEAM agenda needs to be about.” Experimentation, exploration and problem-solving are all important aspects of learning. Unfortunately, “we’ve done a good job of taking this out of education,” she added.

When asked how to bring diverse people into the sciences, Ms Honey said we need to look at ways to provide the broadest access for engagement. How do we use
opportunities to invent, create and open learning for students? It means going beyond engaging children in science through a textbook. “Books are a bad paradigm for learning,” she said. “Make, play, design” approaches would be more effective as strategies to engage the formal education system, and promote learning in STEM. “We have an enormous crisis in STEM education,” she concluded.

“The greatest challenge [for STEM] is around formal education spaces,” agreed Ms Malcolm. “What in science education would art help us do?” Art might help make science more accessible, for example, where art is inspired by nature. Pedagogy that recognizes individuals’ different ways of seeing and knowing is a key element of effective education. A core feature of this pedagogy is inquiry or inquiry-based learning: “If you push out inquiry, it isn’t about science or mathematics anymore.” Other key elements include effective curriculum and performance assessment. However, part of the issue is figuring out what “authentic assessment” looks like, and how this is shared with parents. It also means trying to turn policy discussions from how you assess to determining what you should teach.

Margaret Honey: “Good teaching, good learning is about good observation, a shifting of the lens in a way that can help us learn.” As head of Continuing Studies at RISD, Brian Smith noted that he has a great deal of flexibility in developing informal and certificate programs that respond to a wide range of learners, from 5-year old kids to seniors, and a variety of learning styles.

“In STEM, we remove degrees of freedom,” said Ms Malcolm, “not just in legislating what people have to know, but we push too many ideas at the same time.” There are different paths to knowledge: First, decide what we need to know (“a few big ideas”) then let people come to STEM through different paths. “State the goal and then find the path... you can enter through any path,” she emphasized. Creative people have more opportunities now to work in STEM, and can travel through multiple pathways, she noted. The increasing role and space for creativity in STEM is due in part to the wide availability of technology.

When asked which schools are most effective in STEM and STEAM, Ms Honey replied: “The best schools allow kids to get obsessed, to dive deep into something.” These schools focus on learning deeply, and the process of how we keep learning, and continue to grow. She cited a report by McKinsey Co. on models of success in learning. “Where we get successful models, we don’t legislate learning,” said Ms Honey. “Trust is a critical ingredient in learning. The policy environment is trust but verify.”
we take a leap.” By starting with objective observation, rather than immediately making assumptions, she explained, we avoid shutting down creativity and instead “open it up.”

1:45 PM  RISD NATURE LAB — LEARNING AND RESEARCH SPACES

In the Nature Lab, Director Neal Overstrom guided participants through an exploratory exercise about learning and working with physical objects. Participants were divided into groups, and each group was asked to categorize the numerous objects laid out on a table—shells, bones, leaves, fossils, nuts and other items—into five distinct categories of their own choosing. Each group found creative and unique ways of categorizing the objects, for example, by size, textures, uses, even by the possible sounds the objects could make. How we organize information, concluded Mr. Overstrom, “depends on the story we want to tell.”

3:00 PM  REFLECTIONS / CONVERSATIONS

PAMELA JENNINGS, NSF: REFLECTIONS ON CREATIVE IT AND BRIDGING STEM TO STEAM

Pamela Jennings, NSF program director, gave a brief overview of the Computer Science Directorate’s three-year Creative IT program, which looked at models of creativity and creative cognition by uniting various disciplines and using creativity in software and software development to “problem-solve.” A “gaps analysis” identified the bifurcated world that exists between art and science worldviews. The areas where actions could be taken, she noted, include infrastructure, scholarship, education, the role of NSF, and the building of networks and collaborations. The idea of a workshop to explore how to bring together arts and STEM arose out of “a desire to keep the dialogue going,” she explained.

As a result, NSF is sponsoring three workshops to explore issues and opportunities related to bridging STEM to STEAM. The first workshop, hosted by the National Endowment for the Arts in 2010, involved 60 participants in a highly interactive setting to discuss building bridges between the sciences and the fine, applied and performing arts, and ways to bring these communities together and make them stronger. NSF is interested in exploring other issues and opportunities in this area, including looking at “potentials and symmetries that happen across STEM and the Humanities,” said Ms. Jennings. The third workshop takes place in March 2011, and its aim is to investigate the possible establishment of a network for excellence.

There are a number of drivers and trends related to the growing interest in STEAM, she remarked. Among these are the creative innovation economy, public engagement and learning, interdisciplinary scholarship, and the “democratization of making”, for example, through open source hardware and software. “Technology-based creative spaces are becoming more open,” she explained.

THE CONVERSATION

Chris Rose, a Critic in RISD’s Graduate Studies program and Co-Principal Investigator for the workshop, invited participants to converse and reflect, acknowledging the importance of spaces for thinking and insights, and the value of conversations as a way of “witnessing versus being subjected to a speech.” He then opened up the dialogue to participants by posing a number of compelling questions: What different kinds of learning spaces might there be? How does expert knowledge
connect to naïve inquiry? How do we connect or move between spaces and domains? How do we promote learning spaces for the future?

**Brian Smith** explained that the purpose of this workshop was to explore the range of what STEAM could be, and engage in spaces that will foster ideas about what could be STEAM. He wondered why certain people have the ability to bridge the gaps between arts and sciences, i.e. the “hybrid” people who can talk and converse in both art and scientific spaces. Are there specific educational experiences that foster the development of “hybrids”? “What is it about our learning that made us this way?” he asked. How might we bring the qualities of a hybrid into K-12 grades?

**Johannes Goebel, Director, Experimental Media and Performing Arts Center, Rensselaer Polytechnic Institute**, commented on the difficulties of conducting transdisciplinary work. “Transdisciplinary research usually fails because we are comfortable in our own niches. We do not use the same language and we have different funding structures.” He noted that the aim of the next workshop in March is to look at the viability of establishing a network for excellence to get “beyond the boxes we live in.”

**Mr. Rose** noted the importance of engaging with individuals in a diverse way, and that many people who came to art school did so because they were stepping back from experiences they didn’t like elsewhere.

**Paul Thompson** noted that from a United Kingdom (UK) perspective, art schools are “recruiting grounds for contrarians, ones who have not done well in traditional areas.” The recruiting practice is so different between the arts and sciences, he added. In the UK, the idea of mixing science with humanities is very difficult, and peers in high school are much less encouraging of mixing sciences and humanities. Those who do may end up with a skill set that is not useful or valued later in life.

A participant commented that it would be interesting to do a study of what kinds of people embody STEAM, looking at what kinds of paths they took, and explore what it might lead to in educational programming. Such a study could help inform educational policy, approaches and programs. Another participant noted that many examples of transdisciplinary research and projects already exist, and many places already effectively gather these kinds of people—Silicon Valley, PIXAR and others—and he cautioned against focusing only on academic settings.

**Kirtley Fisher, Legislative Assistant, Office of Congressman James Langevin**, talked about the congressman’s support for STEM to STEAM through the recent resolution passed (H-RES 1702). Congressman Langevin supports the idea of bringing all these disciplines together, and wanted to make sure there’s a “marker” that this [STEM to STEAM] is going on, said Ms Fisher. She also indicated support by the congressman for developing a STEM-STEAM Council.

**FINAL PEARLS OF WISDOM**

**Chris Rose:** We don’t really know what it means to sustain learning opportunities in interdisciplinary contexts. Education needs to be orbiting around student needs and interests. “They are critical to this.”
Brian Smith: “One of the most powerful opportunities is to notice what we notice.”

**MINI-KEYNOTES 1, 2 & 3**

Mini-Keynote 1: Michael Benson, an “image producer,” science writer, photographer, illustrator and filmmaker at Kinetikon Pictures described his planetary landscape photography, a unique amalgamation of art and science. His spectacular images of the solar system are created through culling thousands of shots from decades of robotic space missions. “It is the process of turning raw data into images,” he explained.

Mini-Keynote 2: Richard Wurman, Chairman and Creative Director of TEDMED, talked about truth, curiosity and learning. “Everything that everybody says is the truth. It’s their truth.” He is driven by an “overwhelming physical curiosity to understand things I don’t understand,” he said. In talking about learning and ways of creating space to learn, he offered a new model: “What happens if you sell your ignorance? The important thing is the embracing of our own stupidity,” he suggested. “You need to go backward to go forward in the journey of learning.” He also ascribes to the philosophy of not teaching in absolutes. “Don’t teach absolutely anything. Teach so things can come in and change patterns,” he said.

Mini-Keynote 3: Jonathan Harris, co-creator of We Feel Fine, demonstrated how he combines art, design and technology through information visualization to reveal the secrets and stories of large datasets or “footprints” on the Web. In describing his work, he told something of his own story i.e. “what it’s like to be someone who combines art with STEM,” and his concern about how technology can dehumanize people in some ways. People are “becoming interfaces for machines, as technology merges women and men into androgynous users,” he suggested. His deep involvement in his projects, for example, often leaves him feeling “dehumanized” and he perceives a tradeoff between being a good programmer and being a good person.

Technology gives us a few challenges if we’re going to design places online that are good for people to be in, he posited. Empathy is a major challenge of technology: People need to develop “empathy for their machine” but as a result they can lose it for humans, Harris noted. (Interestingly, his work humanizes technology by revealing human empathy found in large datasets). Another issue is determinism: “if there’s a problem with machines or programs, it can be found and fixed,” he said. “Not so with humans.” Technology can also challenge one’s art of expression, i.e. through “an unfulfilled creative urge that doesn’t get fulfilled” because technology cannot fulfill it.

Overall, we need to guide and enhance digital architecture: The Web is overdone in some areas such as shopping and phone books, and underdeveloped in other areas such as creating spaces like churches, parks, and public spaces. These don’t really exist online yet. “Digital space needs to be designed responsibly,” he emphasized. “It’s more important than ever to understand your own story” in inhabiting these spaces.
DAY 2: FOCUS AND KEY PRINCIPLES


Mini-Keynote 4: Dan Wieden provided an overview of the previous day’s activities and emerging themes, centered on the need for textured and varied learning, and the importance of approaching STEAM not as an additive process to STEM but rather as a fundamental shift in how we learn.

Mini-Keynote 5: Holger Zschenderlein, gave an overview of The Breathing City project at the UK Royal Society Festival of Science 2010, a unique collaboration between an urban meteorologist, a designer, a material practitioner and a composer/sound artist.

Through the use of an audio-visual “Ice – Traffic” installation, with images projected onto ice accompanied by a soundscape of traffic and cracking ice, the aim of the project was to provoke discussion about complex climatic processes in urban environments. The project explored issues of communication and representation of scientific data through artistic practice and united diverse fields of research and practice, within a creative and exploratory dialogue. “Children loved it, they wanted to touch it [installation],” said Mr. Zschenderlein.

He also talked about barriers to transdisciplinary work. “What’s missing are the places where we come together.” He noted that the disciplines are physically separated, and that we need to bridge these geographical divisions. There is a need to create physical spaces for interdisciplinary work and exploration. “Exploration is very important,” he said. Chris Rose, a collaborator in the project, emphasized the importance of “the encounter space as an inclusive space.”

10:15 AM  SMALL WORKING GROUPS: DIRECTIONS, APPLICATIONS AND AMBITIONS OF POTENTIAL STEAM PEDAGOGY

Following breakout discussions, several groups reconvened to share their insights into the questions: (1) What aspects of creative practice and enquiry in the arts and design fields are of interest to scientists? (2) How may the processes of scientific enquiry contribute to arts and design practices?

The first group’s members spoke of breaking down the mind / body dualism, and offered a new and interesting metaphor for STEAM: the concept of “thinkering” = thinking + tinkering. The “opportunity and the ability to cooperate from an intrinsic perspective” was discussed, with intuitiveness and receptivity proposed as two key elements. Finally, moments of inspiration are common among all disciplines, and "we should embrace these moments."

Members of the second group emphasized that emerging unorthodox learning methods and strategies should be encouraged and allowed. Additionally, we all bring our own experiences, knowledge and meaning to things but that this is fluid: As we change, the organization, order, understanding and meaning is different at times. Artists and scientists are confronted with chaos, and try to make meaning of it by seeking patterns within randomness — “in our patterns, we are looking to make things abstract.”
The third group characterized the work of artists and scientists as the ability to “make the invisible visible,” or “to make the unknown, known,” and to see patterns and make associations. Both also ask good questions, and possess great curiosity and drive. Finally, both groups have audiences and want to communicate effectively to their audiences.

The last group noted that artists and scientists “bring emotion, passion, play to their inquiry.” With regards to STEAM pedagogy “we should talk about experience design versus curriculum design” and use groups of terms such as “engage, open, curious, wise.” Finally, learning should encompass an escalation from data to information to wisdom, while developing in students a sense of agency.

In noting differences, STEM’s intention was described as goal-oriented versus art’s process-oriented approach. Artists possess “peripheral visions versus aiming at a target” as scientists tend to do. They also questioned whether objectivity and general “truth” really exist.

11:15 AM
PEARLS OF WISDOM: FACILITATED SUMMARY SESSIONS WITH LYNN CARRUTHERS AND RISD RESEARCH ASSISTANTS

To close the workshop, research assistants were invited to share their impressions, perspectives and stories with the participants. Below are some excerpts.

Peter Simon noted that the workshop opened his mind, and “one overarching thing is that there’s so much change and we need to overcome change. We overcome change by asking questions.” By doing this we get to new methods of learning, he said.

Jessica Fanning expressed her enjoyment of the “purposeful sense of play” throughout the workshop activities.

Another student, Sara Raffo described her work as “Looking at how to create structures and spaces where not knowing can take place.” On her attraction to science: “What drew me to science was listening to stories, amazing stories of discovery. Art and design allowed me to find spaces of experimentation.” Science and art come together and reveal “freedom, truth and joy in the world around us.”

Arthur Yidi said the workshop helped him explore what it means to be an artist or designer. “We are understanding what we really do. A designer who understand science and art is an innovator,” he exclaimed.

Andreas Nicholas talked about the idea of using diplomacy to bridge different ideas. “Diplomacy is coming to a deeper understanding” of learnings from different disciplines and finding a common language, a way people can connect on all levels. “People are able to empower one another through the image they project, through the conversations they have, through the work they’re able to do together,” said Andreas. Finally, he expressed a concern that the STEAM initiative would be coopted by an economic agenda but came to the conclusion that “we have the power to make the economy in service to us, not to itself.”
Tessa Zeng expressed similar concerns about STEAM becoming “innovation inside a box.” “I’m scared that our beautiful ideas are being built on an old broken structure,” she said referring to her fears that capitalism and consumerism would co-opt the STEAM agenda.

Carly Ayres said she enjoyed the “passionate deep dives” of participants in the workshop, similar to how she feels when she does her work and projects. She then offered this pearl of wisdom - “We have this responsibility to take risks, and if we don’t take it, no one else will.”

The last word went to University of Brighton, UK graduate student Tom Ainsworth who stressed that in moving forward on STEAM, it’s important “not to be restricted by what we know.” We should ask “what can these things be rather than recognize them for what they’ve been.”