A Practical Guide to Art/Science Collaborations

SIGGRAPH 2013 Course Notes
Short course (1.5 hours)

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Summary

This course examines the role of Art/Science collaborations, presents historical examples of Art/Science projects, the motivations and impact of such collaborations. It serves as a practical guide by identifying and analyzing the important elements of successful cases, based on research and personal experiences from professionals in relevant fields.

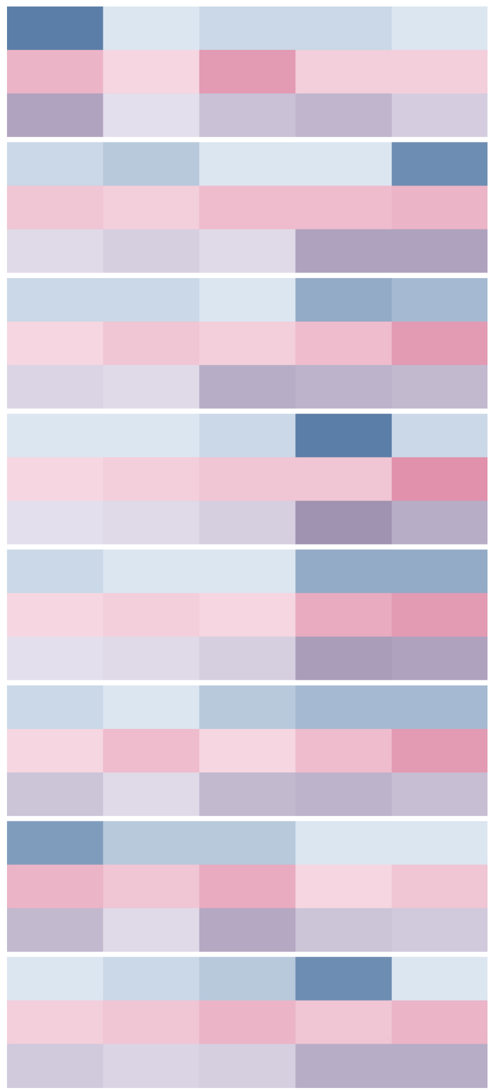

Image: Heat map data visualization of Art/Science Collaboration Research Survey Question 16: "From Your perspective, how important is each of the following outcomes of an A/S project for you? Please base your answer on the most recent collaborative A/S project you participated in." The heat map represents the percentage of respondents that ranked the importance of eight (8) outcomes of A/S collaborations. Each outcome (Patents, Publications, etc.) is represented by a group of three rows. Within each outcome, the first row (blue) corresponds to answers supplied by Scientists, the second (pink) to those supplied by Artists, and the third (purple) by those who self-identified as "Both a Scientist and an Artist". Columns from left to right correspond to the degree of importance of each of the eight outcomes, from "Not Important" to "Very Important". The percentage of responses for each degree of importance is signified by the lightness of the cells: high percentages correspond to darker colors.

Intended Audience

Everyone interested in Art/Science collaborations. Artists, Scientists, Educators, industry specialists, project managers, students, and anyone who is interested or involved in interdisciplinary collaborative teams between artists and scientists.

Prerequisites

None

Level

Introductory

Bio Forms

Dan Sandin
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Dan Sandin is a video and computer graphics artist/researcher. He is a Professor Emeritus of the School of Art & Design, University of Illinois at Chicago. He is a co-founder of the Electronic Visualization Laboratory (EVL) at the University of Illinois at Chicago, the first formal A/S collaborative research program in the United States. He is an internationally recognized pioneer in computer graphics, electronic art and visualization and his work embodies an interdisciplinary fusion. Sandin, who came to video and computers in the 1970s with a background in physics, was instrumental in the development of imaging devices that could be made accessible to artists for their own duplication and use. He is the inventor of the Sandin Image Processor, a patch programmable analog computer for real-time manipulation of video inputs through the control of the grey level information. Dan Sandin is a father of the CAVE, the CAVE Automatic Virtual Environment, which he developed in collaboration with Tom DeFanti and art and science graduate students in 1991. Sandin's computer/video art has been exhibited at conferences and museums worldwide, and he has received many awards. Sandin has received many grants and fellowships from such distinguished organizations as the Rockefeller Foundation, the Guggenheim Foundation, and the National Endowment for the Arts; his work is included in the inaugural collection of video art at the Museum of Modern Art in New York.

Daria Tsoupikova

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Daria Tsoupikova is an Associate Professor in the School of Art and Design and the Electronic Visualization Laboratory (EVL) at the University of Illinois at Chicago. Her research and artwork includes development of virtual reality (VR) art projects and networked multi-user exhibitions for VR projection systems, such as the Cave Automatic Virtual Environment theatre (CAVE), as well as the design of interactive educational multimedia for children. Her virtual reality research, publications and artwork explore the relationship between the aesthetics of virtual environments, traditional arts, and the effect of virtual reality aesthetics on the user's perceptions and emotions. Her work lies at the crossroads of artistic and technological innovation, and explores the potential of new media and interactivity in relation to traditional arts. Her current works are applications of computer graphics art to various research domains such as educational multimedia, cultural heritage and virtual rehabilitation for stroke survivors. Her work was exhibited and published at SIGGRAPH, IEEE VR and ISEA and many other venues.

Course Description

This course serves as a practical guide to Art/Science collaborations. The purpose of this introductory course is threefold and intended to provide artists and scientists with advice on how to: 1) prepare them for such collaborations, 2) improve existing collaborations, and 3) foster such initiatives. The notes are aimed at anyone who is interested in such collaborations, including artists, scientists, educators, students, project managers and industry specialists, irrespective of prior experience. The course will also include a brief historical overview of A/S collaborations up to the current state of the art, presented by computer graphics pioneer Dan Sandin, who carries a 35-year experience of participation in such projects. Dan Sandin will augment the presentation by sharing his experiences as an artist, scientist and educator.

This course is structured as a short course (1.5 hours). In the second section of the course we will introduce the collaborative research study initiated by the authors of this course and present its results regarding the important elements of a successful A/S collaboration. We will share personal advice from professionals with significant experience in A/S collaborative research as well as provide references to their experiences. Finally, we will present three case studies of A/S collaborative initiatives and share critical advice from the project authors.

Course Schedule

(3 minutes) Instructor: Dan Sandin

Overview of the course goals and content.

(27 minutes) Instructor: Dan Sandin

A/S collaboration: History, impact, and current state of the art.

(35 minutes) Instructor: Daria Tsoupikova

Practical advice for successful A/S collaborations, based on results of a collaborative research study and personal advice from the authors of this course and professionals with significant experience in A/S.

1 Introduction

1.1 Motivation and purpose of the course

Art/Science (A/S) collaborations have propelled cultural, historical and technological evolutions in our society and have gained more importance as research programs in industry and academia recognize the significance of multidisciplinary approaches, lateral thinking and creative engagement in the process of innovation. However, despite this growth and development, the methodology for A/S collaboration has yet to become a subject for research and implementation in mainstream cultural institutions and educational programs. While many educational institutions recognize the importance of dialogue between artists and scientists, still only a handful of contemporary institutional programs have developed curricula that engage students in such projects or teach strategies on how to achieve collaboration. There has been significant controversy about whether artists and scientists have different cultures, motivations, aspirations, approaches and measures of accomplishment. So, the key questions have become:

- *How can we prepare both sides and educate them about each other's views?*
- *How can we foster A/S collaborations?*
- *How can we improve such collaborations?*

1.2 Introduction of A/S research team

In October 2011, with the above questions in mind, the Art/Science Collaboration Research Project was initiated aiming to provide practical advice to artists and scientists and prepare them for A/S collaborations. We are a small group of researchers consisting of scientists, artists who also hold scientific backgrounds, and a professional evaluator. Our experience in the field is derived from our participation in A/S collaborations for over a decade for two team members (Daria Tsoupikova and Helen-Nicole Kostis), 25 years of experience for our Advisory Board member Marie-Theresa Rhyne and 35 years of experience for Dan Sandin. The members of this collaborative team have worked in the fields of virtual and augmented reality, scientific visualization, cultural heritage, web and mobile/app development and computer games. They have been involved in a wide variety of projects: large and small, with many or few team members, lengthy or short in duration, with or without funding, successful or not. With time, they started identifying patterns and elements that make these collaborations easier. For this course, they extracted those patterns, converted them to hypotheses and validated them by analyzing a survey designed for scientists, artists, and participants with both backgrounds who have experience in A/S projects.

1.3 Overview of the course content

The first part presents briefly the contemporary history of A/S collaboration, its impact and state of the art today. Sections 2.1 and 2.2 describe A/S collaborations with illustrative examples described in section 2.2.1. Section 2.3 describes motivations and reasons for artists and scientists to participate in the A/S collaborative initiatives. It also covers expectations, contributions and outcomes characteristic of such projects.

The second part provides information about the recent research survey on A/S collaboration developed and ran by the authors of this course. Section 3.2 identifies the important elements of a successful A/S collaboration supported by data from the survey in the following areas; planning, goals, communication methodologies, funding, management, technology, skills, and opportunities for A/S collaborations. In this section of the course personal advice from professionals with significant experience in A/S collaborative research is shared, as well as references to their experiences.

The last part of the course provides the details (goals and lessons learned) of three case studies that illustrate how scientists and artists work together in research, academia and industry.

1.4 Acknowledgements

We would like to especially thank all the anonymous scientists and artists that participated enthusiastically in the survey and for their thoughtful feedback. Special thanks to Theresa-Marie Rhyne and Dan Sandin, the advisory board of this research team for their guidance and support. Thanks to Maxine Brown for all the helpful advice from the beginning of the project. Special thanks to Stephen Melamed and Michael J. Scott, the leaders of the Interdisciplinary Product Development Program at UIC Innovation Center. This research is partially supported by the Dean's Research Award of the College of

Architecture and the Arts, University of Illinois at Chicago. *This research has been approved by University of Illinois IRB (protocol number: 2012-0200)*

2 A/S Collaboration Background & Experiences

2.1 What is A/S collaboration?

Art/Science collaboration is the collaboration between artists and scientists that generates projects, processes, experiences, knowledge, ideas, and organizations beneficial to both fields. Results of art/science/technology collaborations directly can affect educational and pedagogical practice and society at large.

The movement to integrate science and art to examine convergence points, and how the fields can empower each other, has already begun. In the last few years, there have emerged a number of meetings that study art and science convergences supported by efforts of the National Science Foundation (NSF), the National Endowment of the Arts (NEA), the Association for Computing Machinery (ACM), the Conference on Human Factors in Computing Systems (HCI), as well as other institutions (Comer 2011; STEAM 2011). Despite these efforts, the integration of arts and science in industry, research and education, the roles of artists and scientists and their contributions to the success or failure on collaboration have yet to become subjects for research and implementation in mainstream cultural institutions and educational programs.

2.2 Contemporary history of A/S collaboration

"Cybernetic Serendipity" (London, 1968) was the first formal exhibition to explore 'the relationships between technology and creativity' (MacGregor 2002). This legendary milestone in the history of A/S collaboration included robotics, algorithms, devices for generating music, kinetic environments, moving images, installations, procedural animation, and computer graphics images produced on cathode ray oscilloscopes and digital plotters. Teams of artists, scientists, and engineers experimented in a most daring way with concepts and technology, which created the body of work that emerged as a cultural landmark.

Different forms of collaborative art and science works and research started to become apparent in the late 1980's with the advancement of technology. Such collaborations flourished in the 90’s after the computer became an affordable part of daily life. The establishment of the first collaborative research institutions such as the Electronic Visualization Laboratory at the University of Illinois at Chicago, the Computer Graphics Research Group at the Ohio State University and the Computer Science Department at the University of Utah in the mid 70s created key centers for experimentation at the nexus of arts and sciences. Exhibitions of A/S collaborative projects have continued over the last forty years in conferences and festivals such as ACM SIGGRAPH, Ars Electronica, ISEA and in Science Centers, such as the Exploratorium and many other institutions. There are numbers of fields that transcend the historically assumed boundaries between art and science and inform each other such as Computer Graphics, Computer Generated Animation, Biomedical Illustration, Scientific Visualization, Medical Visualization, Virtual Reality, Science Photography, Architectural reconstruction, Computer Games etc.

2.2.1 Examples of Art/Science collaborations

In this section Dan Sandin will introduce his background (scientific and artistic) to the course audience and share his professional experiences, while establishing the Electronic Visualization Laboratory, at UIC with Tom DeFanti. The slides below include part of the information that will be shared with the course audience.

Electronic Visualization Laboratory (EVL)

- 39 years of art / science collaboration at UIC
- Joint program: CS and Art & Design departments
- First program in the US offering MFA that is a formal collaboration of art and computer science

Electronic Visualization Laboratory (EVL)

- EVL delivers art intelligence to scientists and science or technology to artists
- Systematically teaches the artists the technology, and less systematically teaches the computer scientists the art
- The experience of artists is central to the success of EVL

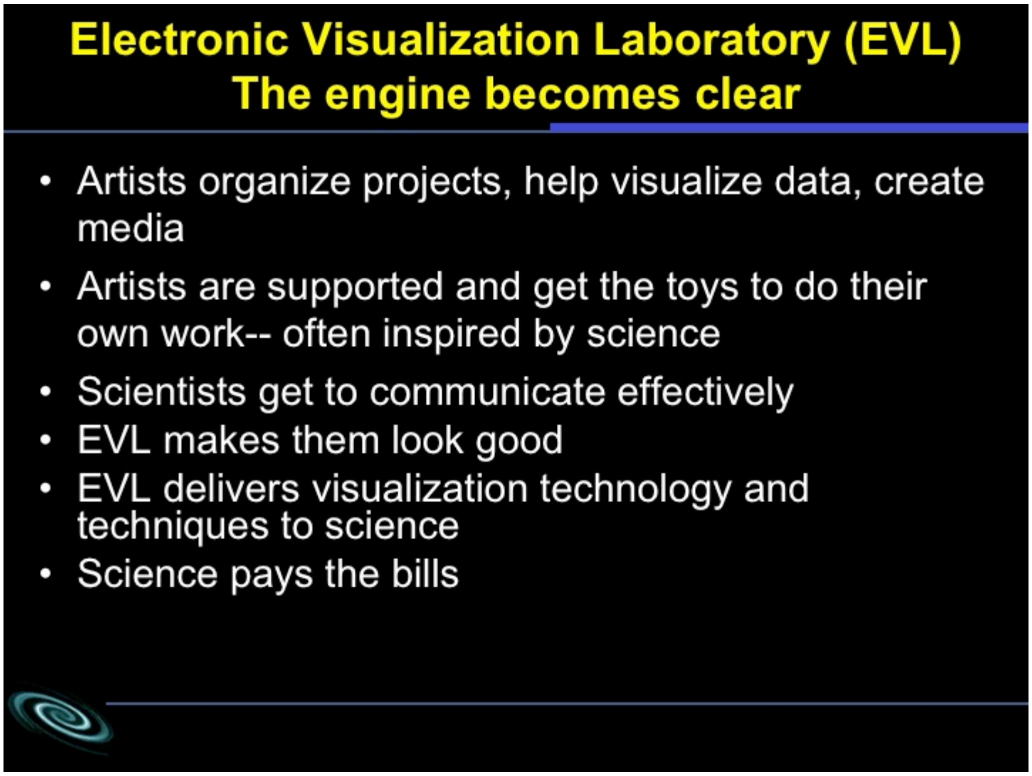
Electronic Visualization Laboratory (EVL)

- 1969 Dan Sandin is invited to UIC's art dept. to bring computers to the art curriculum
- Art Departments are still arguing about the role of computers in the art curriculum?
- ID founded 1937 by Moholy-Nagy, moved to IIT 1949
- Bauhaus house lineage of UIC Art Dept.

University of Illinois at Chicago

Electronic Visualization Laboratory (EVL)

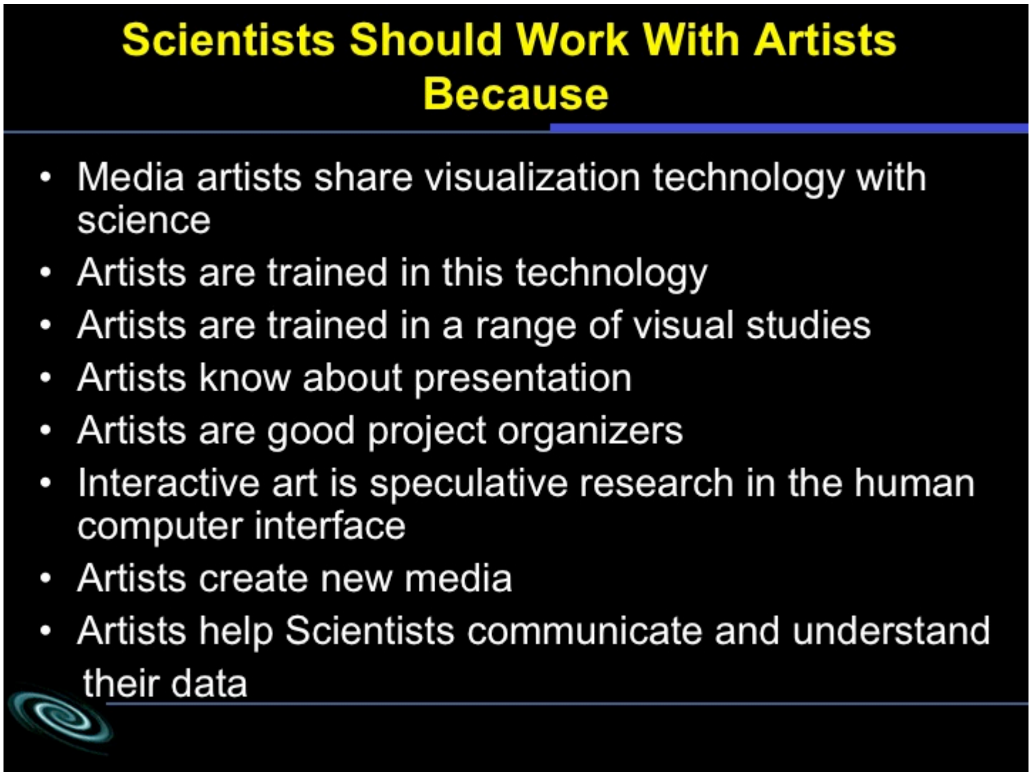
- 1973 Tom DeFanti comes to UIC with the GRASS system, EVL begins as a short order media house for education and research
- 75 76 78
- EVE events



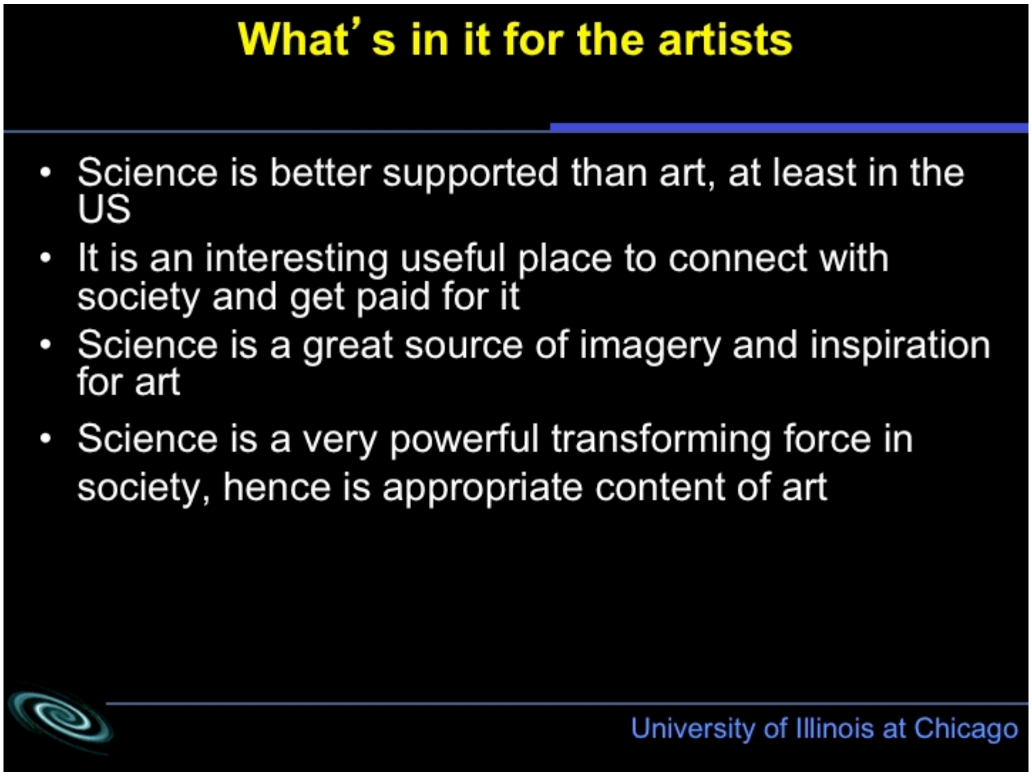
Additional examples will be presented derived from academic, government institutions, and the industry.

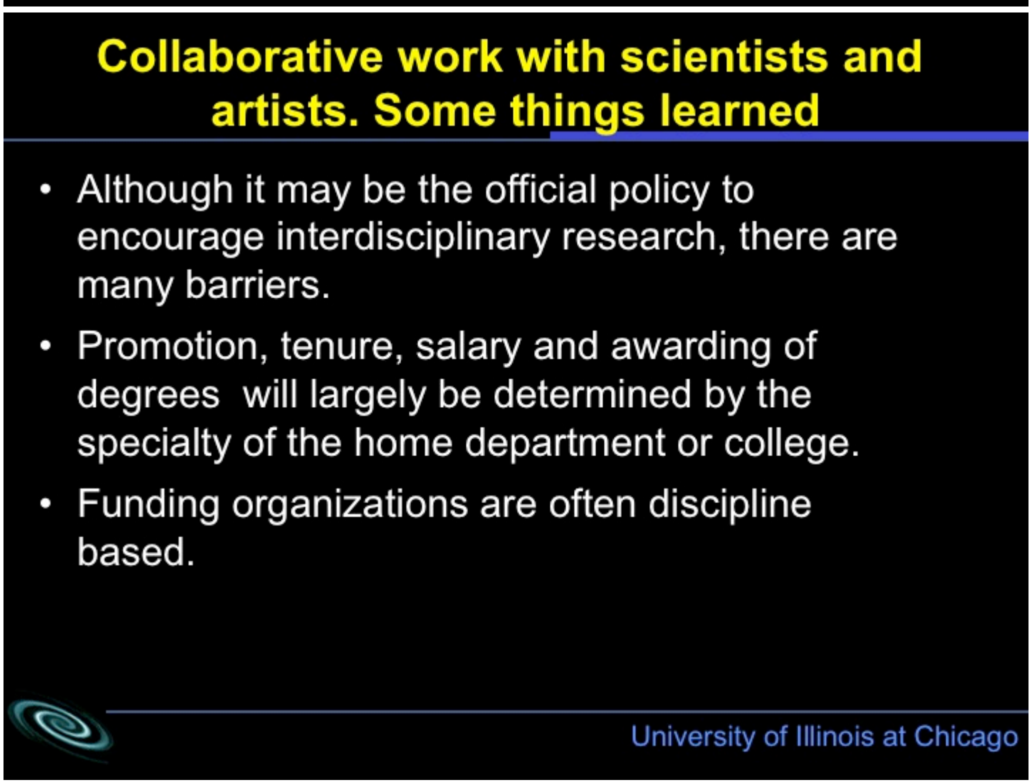
2.3 Motivations

2.3.1 Why scientists need artists?



2.3.2 What’s in it for the artists?





Collaborative work with scientists and artists

- All the collaborators must get rewards in categories that are relevant to them
  - Published papers for Scientists
  - Exhibitions for artists
- Pay everybody

Collaborative work with scientists and artists

- Primarily work with scientists that have a visual or imaging tradition
- Primarily work with artist that have electronic media training
- Take on problems that have a geometric interpretation

3 Research-Driven Development: A Practical Guide for Successful A/S Collaboration

3.1 A/S research survey

3.1.1 Survey design

The presented research is based on a 42-item anonymous online survey questionnaire relating to collaborators' experiences in Art/Science collaborative projects. The survey was sent to targeted groups of specialists (more than 100 subjects) from various scientific and artistic fields. The objective of the survey was to examine practical matters that scientists and artists face when working together on projects and to ascertain barriers and facilitators to a successful A/S collaboration. The survey questions were designed to provide an assessment of the scientists' and artists' subjective experience working with each other. The questions were targeted to provide input from scientists and artists from all disciplines, as well as professionals that have both backgrounds. For example, we considered scientists from the fields of computer science, mathematics, physical and life sciences, and social and applied sciences (technology, engineering). We considered artists of all disciplines as well, including visual, performing, media, applied and computer arts (Figure 1, Please see the complete table of all respondents' fields in the References section). The survey targeted scientists and artists who had already participated in more than one A/S collaborative projects. The survey questions were based on a pilot study that was conducted in 2011, addressing a group of scientists (50+ specialists) who had worked on 6 or more A/S collaborative projects and examined their experiences in A/S collaborations.

Figure 1. Word cloud representation of data provided in the survey question: "Please specify what you would consider your primary field using one to two keywords."

Our survey contained two different types of questions: 29 structured multiple-choice questions and 13 non-structured questions; where the specialists were encouraged to reply at length in order to provide their comments and feedback. We carried out a pre-study involving five colleagues concerned with our research. The goal of the pre-study was to refine the content and structure of the survey. After receiving the input from the pre-study, the survey was revised and the questionnaire was updated. An email invitation with a link to surveymonkey.com was emailed to a targeted group of scientists and artists along with a cover letter and a brief introduction to the study.

The survey had an optional question, which asked specialists to share links/references/bibliography and a narrative description of A/S collaborative projects their had participated in. This question was linked to a separate database, so that responses to this question would not compromise the anonymity of the data from the rest of the survey.

3.1.2 Survey results

The survey was open for feedback for a 2-week period. We overall received 68 responses. Some of the participants in the study indicated that they had no A/S collaborative experience and consequently were not included in the data analysis. Still, we were able to select an experienced group of specialists as 50% of subjects reported to have worked on 6 or more A/S collaborative projects. On average the total time spent on A/S collaborative projects was reported between 2 and 3 years.

The survey asked the participants to indicate if they consider themselves as artists, scientists or both an artist and a scientist, as some contemporary professions operate in both fields. Interestingly enough 53% of all participants answered that they are both artists and scientists (While 22% answered as scientists and 25% answered as artists) (see Figure 2). The number of participants who consider themselves as artists and scientists was an unexpected majority. Due to this interesting result, we plan to follow up with this group of specialists to learn more about their education, background, projects and experiences in an upcoming version of the survey within 2013.

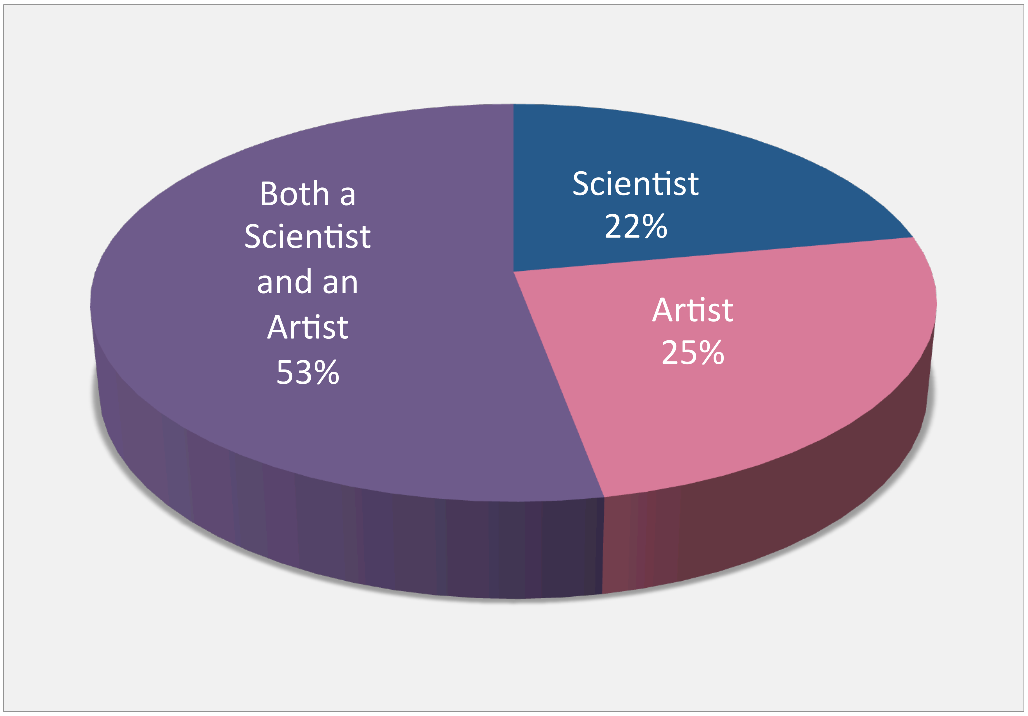


Figure 2: Data chart from Art/Science Collaboration Research Survey Question 3: "Would you consider yourself a scientist or an artist or both?"

The survey results indicate that 73% of scientists rated their collaborative experience with artists as very good or excellent (Figure 3). We asked specialists to describe their personal collaborative experiences using 3 keywords. We analyzed the result text data using word cloud visualization (Figure 4). The most common words that equally stand out of the whole data are: *Frustrating, Enlightening, Challenging and Rewarding*.

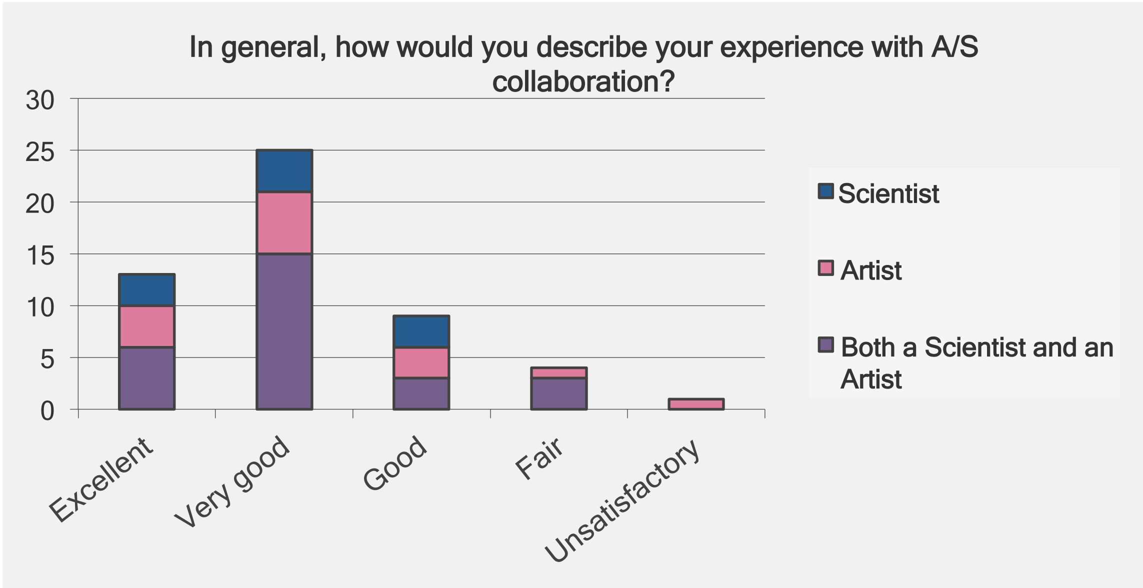


Figure 3: Graph representation of data analysis of A/S Research Survey Question 8: "In general, how would you describe your experience with A/S collaboration?"

By analyzing the questionnaires and the comments, we found that collaborators who experienced frustration during the collaboration reported also other types of problems, including lack of: communication, funding, management, common language between all project members.

Please note that statements in quotes (unless referenced) in the rest of the course notes are extracted from open-ended questions from the survey.

Figure 4. Word cloud representation of data provided in the survey question: “Please list 3 words that describe the impressions the A/S collaboration experience left you with.” The font size of each word is associated with the frequency it appeared in the survey answers.

3.2 Practical suggestions for A/S collaboration

3.2.1 Prepare for collaboration:

“Choose collaborators wisely”. “It is imperative that you “Sit down and talk” with potential collaborators, “get to know each other” and see if you “can actually work together” as a team. The majority of specialists agree that the best way to prepare for collaboration is to ask collaborators to share highlights, discoveries, news and trends (74%)(Figure 5). Organizing a seminar in the beginning of the project was recommended by the majority of subjects (51%). In addition, attending presentations describing your collaborators fields was indicated important (49%).

	Scientist	Artist	Both a Scientist and an Artist	Response Totals
Attend presentations describing your collaborators fields	33.3% (3)	53.8% (7)	51.9% (14)	49.0% (24)
Ask collaborators to share highlights, discoveries, news and trends	**66.7% (6)**	**76.9% (10)**	**74.1% (20)**	**73.5% (36)**
Register for relevant organizations and newsletters	0.0% (0)	38.5% (5)	7.4% (2)	14.3% (7)
Organize a seminar in the beginning of the project	**66.7% (6)**	61.5% (8)	40.7% (11)	51.0% (25)
Not sure	0.0% (0)	7.7% (1)	14.8% (4)	10.2% (5)
Other	11.1% (1)	0.0% (0)	18.5% (5)	12.2% (6)

Figure 5. Responses to A/S Collaboration Research Survey Question 15: "In preparation for collaboration which of the following things would you like to do?"

Most of the specialists across the disciplines (art, science and both) unanimously prefer workshops as the best way to educate artists/scientists about collaborative projects (33%) (Figure 6). Web video, multimedia, webinars, lab/studio tours were recommended for preparation as well. In addition, many specialists emphasized the importance of discussions and face-to-face meetings in person and with the entire group.

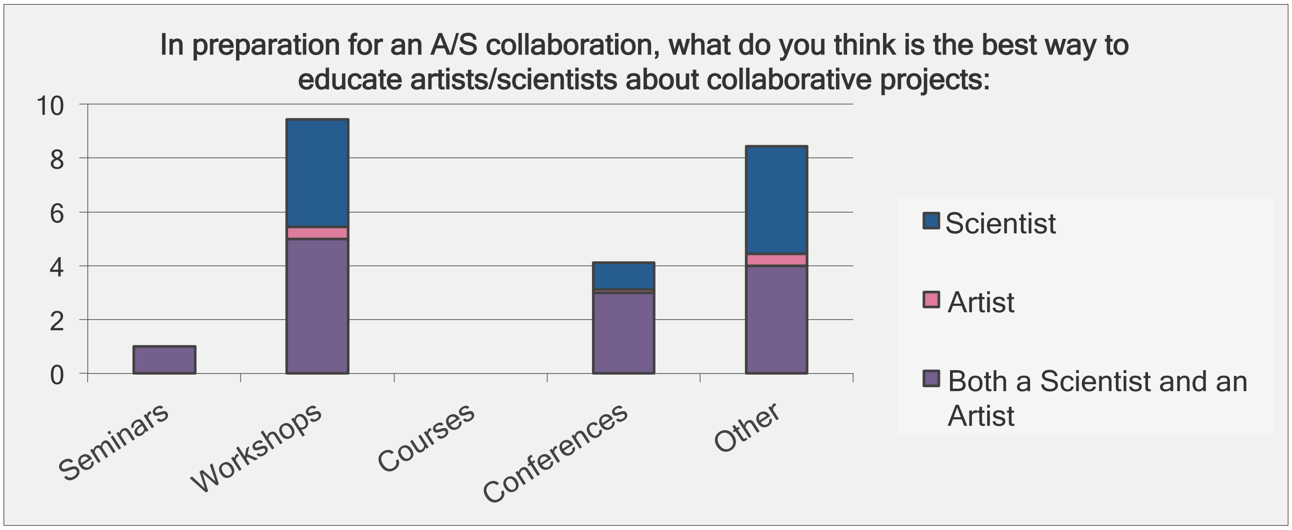


Figure 6. Graph representation of data analysis of A/S Collaboration Research Survey Question 19: "In preparation for A/S collaboration, what do you think is the best way to educate artists/scientists about collaborative projects."

3.2.2 Secure funding:

One of the important aspects of preparing for a collaborative project is to secure funding (seed or long term funding). We asked specialists if they had received any funding to conduct their last collaborative project. The majority answered yes (74%). More than 47% of specialists indicated that it is unlikely they would have pursued the project without funding. However, while 33% of scientists said that they were likely to pursue the project with no funding, the number of artists in this category was 0% (Figure 7).

In a subsequent question, we asked the participants to rate their satisfaction with the funding sources in their last A/S collaboration. A majority (50%) of scientists indicated that they were very satisfied or satisfied with the funding they had received. However, only 20% of artists were very satisfied or satisfied with the funding in their last collaborative project. Furthermore, an equal percentage of artists (20%) were very dissatisfied with the funding, while the number of very dissatisfied scientists was 0%. 70% of participants that are both artists and scientists were satisfied with the funding and only 18% not satisfied.

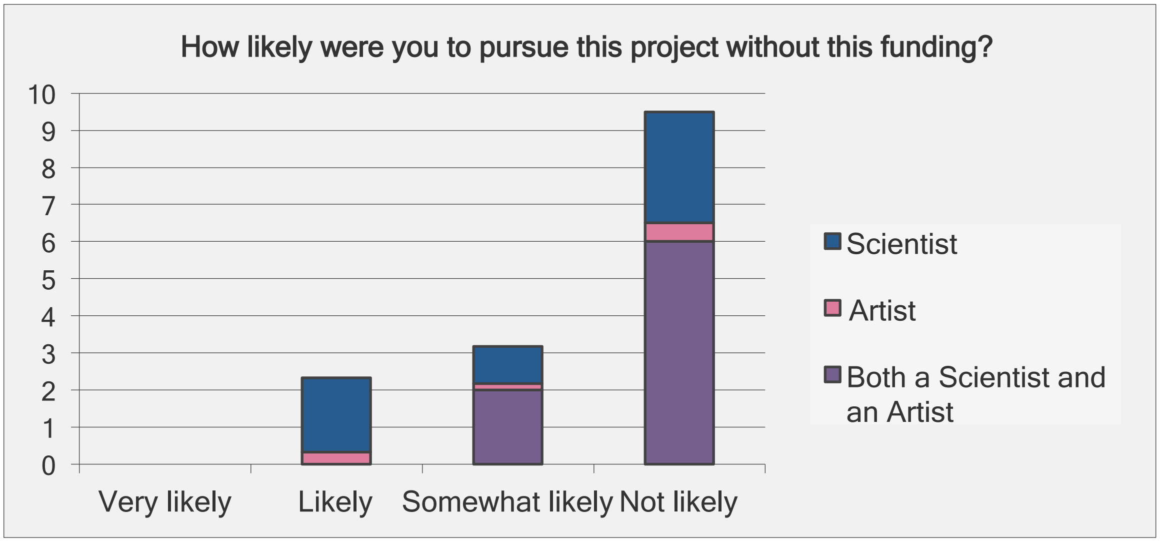


Figure 7. Graph representation of A/S Collaboration Research Survey Question 11: "How likely were you to pursue this project without this funding?"

Out of these last collaborations, 66% were mostly funded by Science, 11% by Art and 23% received an equal amount of funding from Art and Science. The most common active funding sources were indicated as NSF (29%), NIH (11%), private funding (14%), grants (14%), and University and government institutions. Some of the other funding sources were listed as NEA, DOE, NEH, McCarthur Foundation, EU government and commissions, corporate funding, honoraria, self and museum commissions (Figure 8).

Figure 8. Word cloud representation of data provided in the survey question: "What are the most common funding sources for the kinds of A/S projects you do? Please list them." The font size of each word is associated with the frequency it appeared in the survey answers.

3.2.3 Define and learn common language:

Common language is one of the most important elements of A/S collaboration. When we asked specialists how satisfied they were with common language in their last A/S collaboration, while 60% of scientists were satisfied, artists were equally divided (33% satisfied and 33% dissatisfied), and 46% of specialists in both disciplines were satisfied. Interestingly enough, when we asked to rate the importance of common language between collaborators all scientists (100%) rated it as very important or important element of successful A/S collaboration. However, 29% of artists stated it is unimportant or neither, with 71% of artists considered it as an important element.

3.2.4 Heighten mutual respect and trust:

Other important elements are mutual respect and trust between members of the team. However, for scientists mutual respect and trust are more important than for artists: 100% of scientists said that mutual respect is very important and 78% said the same about trust. Among artists 71% said mutual respect is very important and 7% said it is neither important nor unimportant. 57% of artists rated trust as very important and 21% said it is neither important nor unimportant.

3.2.5 Adhere to timeline:

Timeline or achievement of goals in timely manner was reported that needs more work, especially among scientists. 50% of scientists were dissatisfied with the timeline or with how the planned project schedule succeeded. Among artists 67% were satisfied and among specialists in both disciplines 66% were satisfied. Majority of specialist agree that achievement of goals in a timely manner is very important or important (70%).

3.2.6 Don't forget to acknowledge your colleagues:

While the majority of all subjects was satisfied with their acknowledgements, some artists were more dissatisfied than scientists with the proper acknowledgements of their contributions in their collaborative A/S projects: 20% stated that they very dissatisfied or dissatisfied on this subject. Among scientists this number was 0%. 83% of artists stated that an agreement to acknowledge all team members is very important or important.

3.2.7 Appoint proper management and leadership:

Openly discuss expectations and define the roles and responsibilities before starting the project. In responding to the question about management in the last A/S collaborative project, 70% of scientists were satisfied while only 52% of the artists answered the same. 33% of artists were in general dissatisfied with project management. Regarding the leadership within the team, 80% of scientists were happy about it, and only 53% of artists regarded it as satisfactory. Artists and scientists agree (100%) that project organization

and definition of team member roles and responsibilities is a very critical element of A/S project management.
Assuming everyone brings knowledge and expertise to the project and works well with others, the next most critical element for the success of the project is its management. With good management the team will be able to: 1) clearly define goals, roles, timelines and deliverables, and 2) communicate the process and progress clearly and frequently. So, embrace project management methods. It will help you become a strong asset to the team and make the project a reality.

3.2.8 Learn the terminology:

It will benefit everyone in the team if project members become familiar with the languages of cross disciplines involved in the project. Occasionally, specialists encounter difficulties when trying to communicate scientific or artistic methods without relying on specific terminology. We asked artists if **s**cientists should understand artistic terminology and we asked scientists if artists should understand scientific terminology. Majority of artists (54%) said they neither agree nor disagree with the statement and for scientists the numbers were split (38% neither agree not disagree and 38% agree). Knowing relevant expressions and keywords thoroughly helps artists understand the scientific field they work in.

3.2.9 Understand the technology:

An overwhelming majority (81%) of the specialists agreed that it is important that the collaborator has a general understanding (not in detail) about the capabilities, time required and limitations of the technologies utilized in the project. Evidently this importance is a higher priority for scientists (89%) and lower for artists (58%) (Figure 9). Comprehend what is possible (as well as what is not), recognize the technical challenges and become familiar with the inputs and outputs of the system.

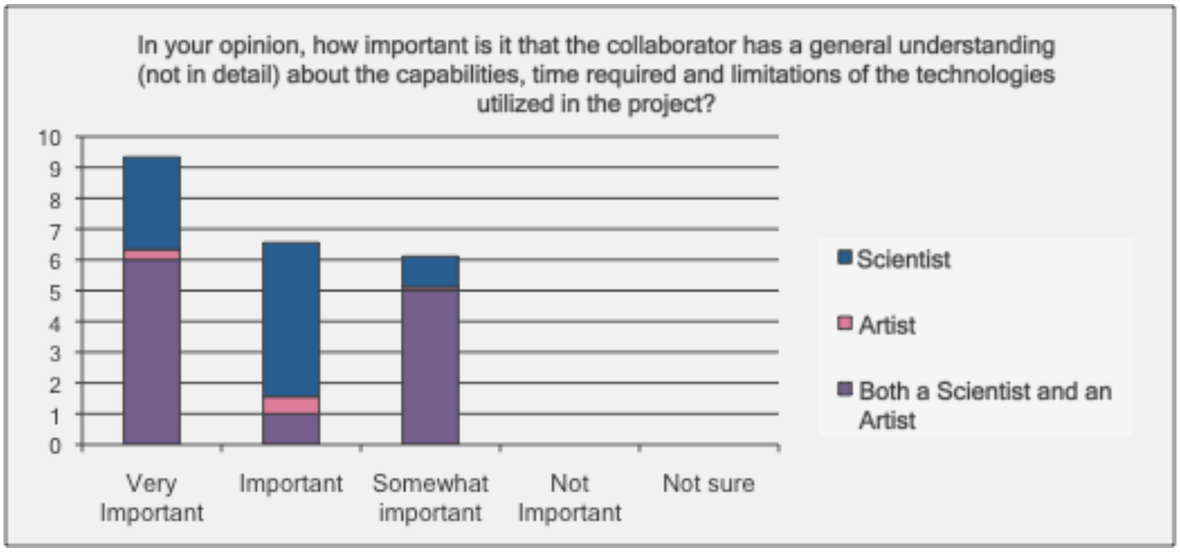


Figure 9. Understanding technology is important. Graph representation of A/S Collaboration Research Survey Question 17.

3.2.10 Sharpen your skills:

We asked scientists if the artist-collaborator should learn/have specific skills (ex. programming, data analysis, understanding of statistics, entrepreneurial) to work with the scientific subject matter in their field. 63% of scientists considered this not necessary. However, scientists commented that analytical skills, understanding of the overall concept of the science, understanding of programming concepts and limitations of hardware/software would be advantageous.

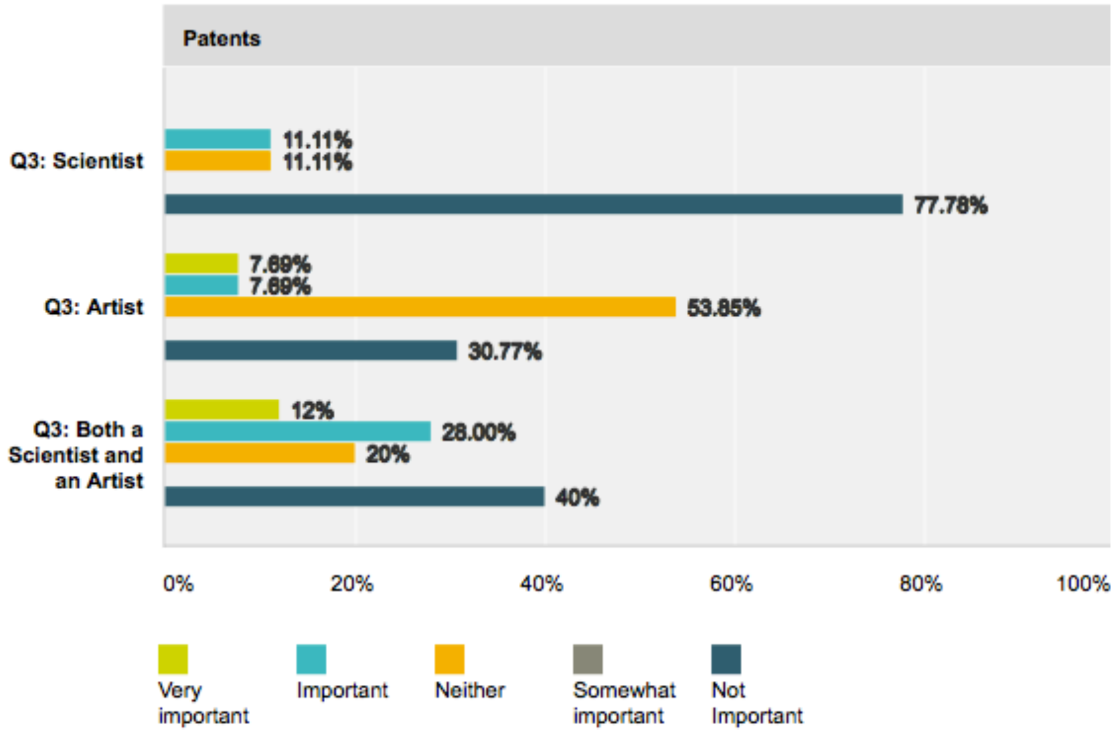
We asked artists the same question about scientist-collaborators (if he/she should understand the importance of specific concepts (ex. Color theory, form, perspective, composition, etc.) to work on the A/S collaborative project. Only 23% of artists believed it was necessary. Artists indicated that basic understanding of the history, art history, conceptual practices, critical theory, the elements and conventions of media arts such as photography, film, video, design, iterative prototyping and interface design could be helpful. In general, it is important that the scientist collaborator understands the concept of what art is because scientists keep asking "What is art's function?"

From the artists' point of view, among the most important skills the collaborator should have are: programming, open mind, conceptual art, design, media art history, creative processes, and to know that not everything is quantifiable. Scientists believed that the skill requirements vary with each project, but the most common skills an artist collaborator should hold are: understanding of basic programming, research skills, data, visual design, scientific inquiry and theory, and willingness to learn new things. It should be pointed out that both scientists and artists agreed that programming and fundamental differences between art and science are the most important skills for collaborators.

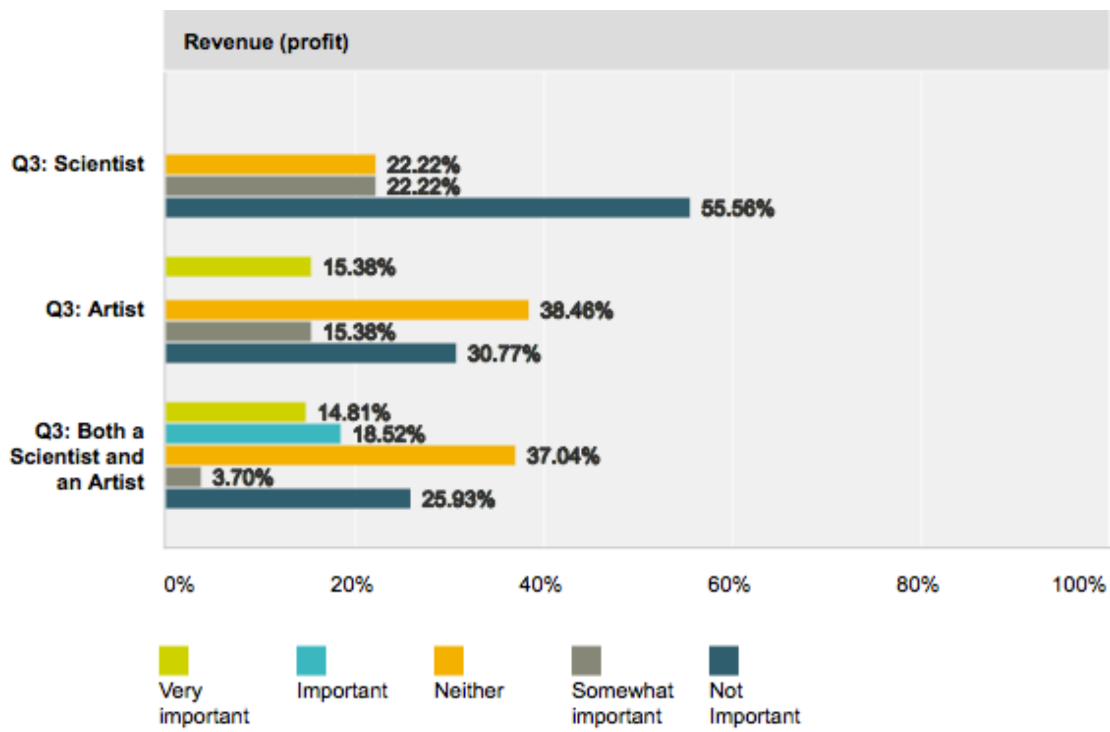
3.2.11 Clarify the outcomes:

Based on the survey responses the majority (78%) of scientists agreed that patents are unimportant. In addition, 0% of scientists characterized revenue as important (Figure 10). The most important outcomes of collaborative A/S projects for scientists were public outreach (90% said it is important or very important) and conferences/presentations (89% said it is important or very important). For artists the most important outcomes were conferences/presentations (92% stated it is important or very important). Surprisingly, exhibitions in art venues and galleries were less important (77%) for artists along with exhibitions in museums and science centers (77%) and public outreach (77%). Specialists in both fields indicated public outreach and conferences/presentations as the most important (85% each) along with publications (81%).

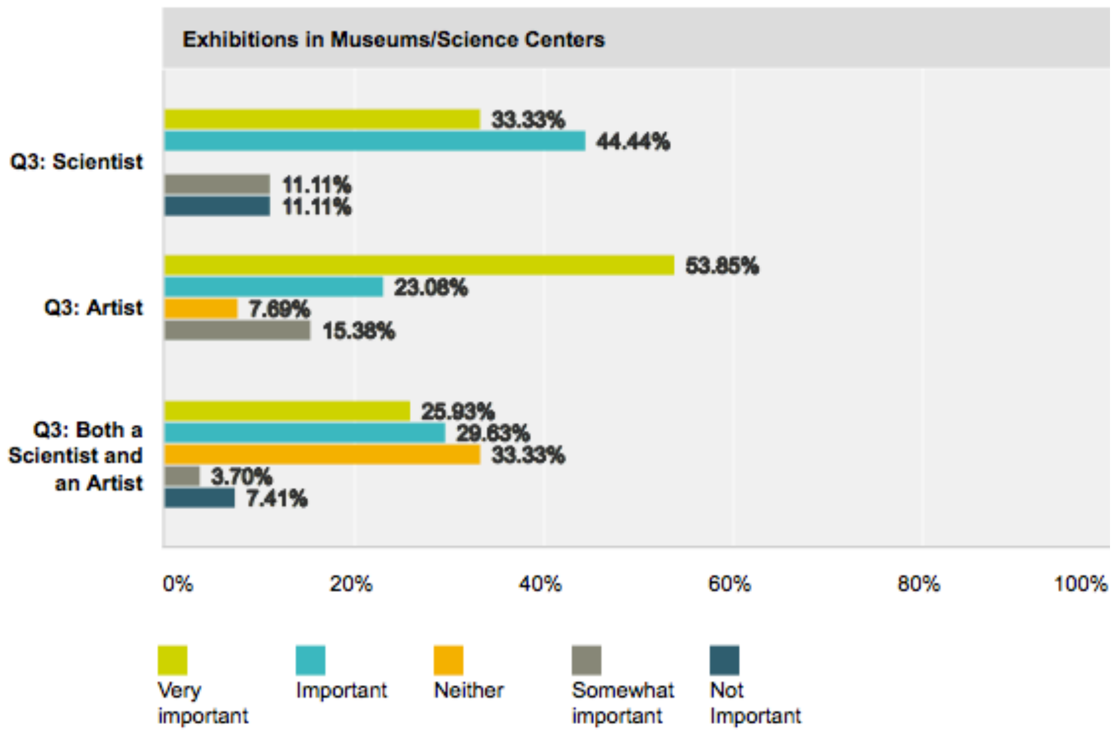
An overwhelming majority of the specialists considered public outreach very important for their work, while least important was revenue (profit). Public outreach encompasses activities and educational programs that bring the exciting message of science and art to everyone and generate awareness of the societal value of research. Such programs include: Museums and Science Center exhibits, educational hands-on activities, interactive installations, games, workshops, etc. Roll-up your sleeves, because your creativity is in demand and get ready to take your artistic vision, skills and collaborative products where they are needed.

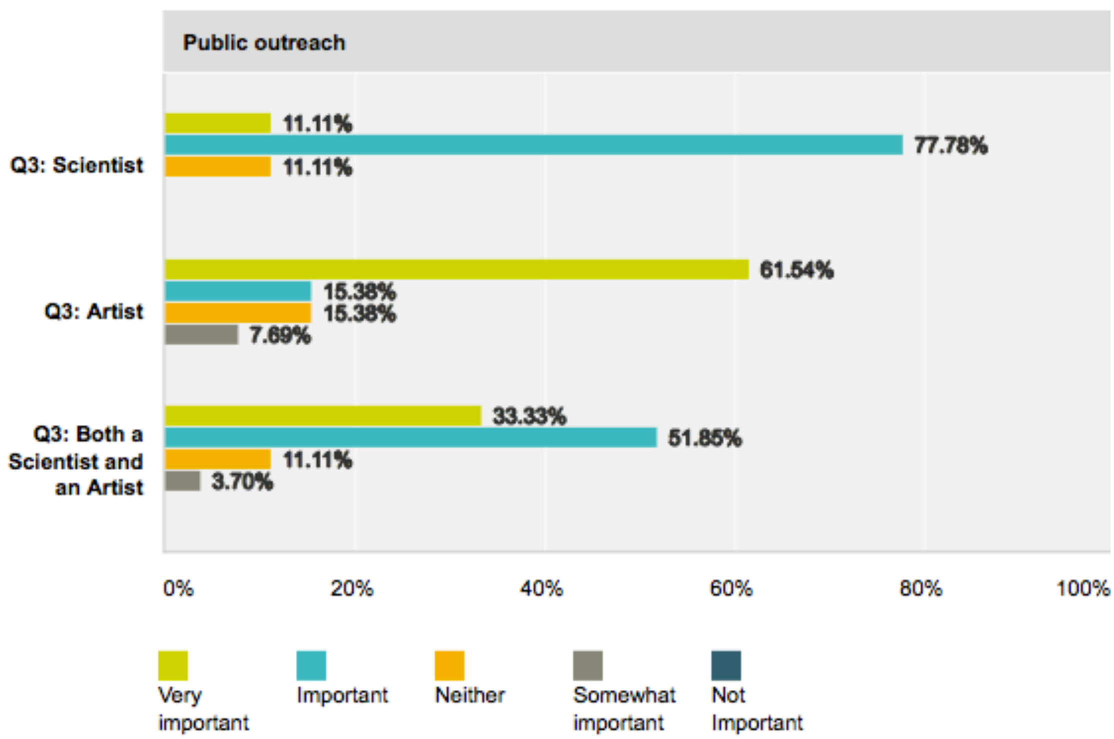


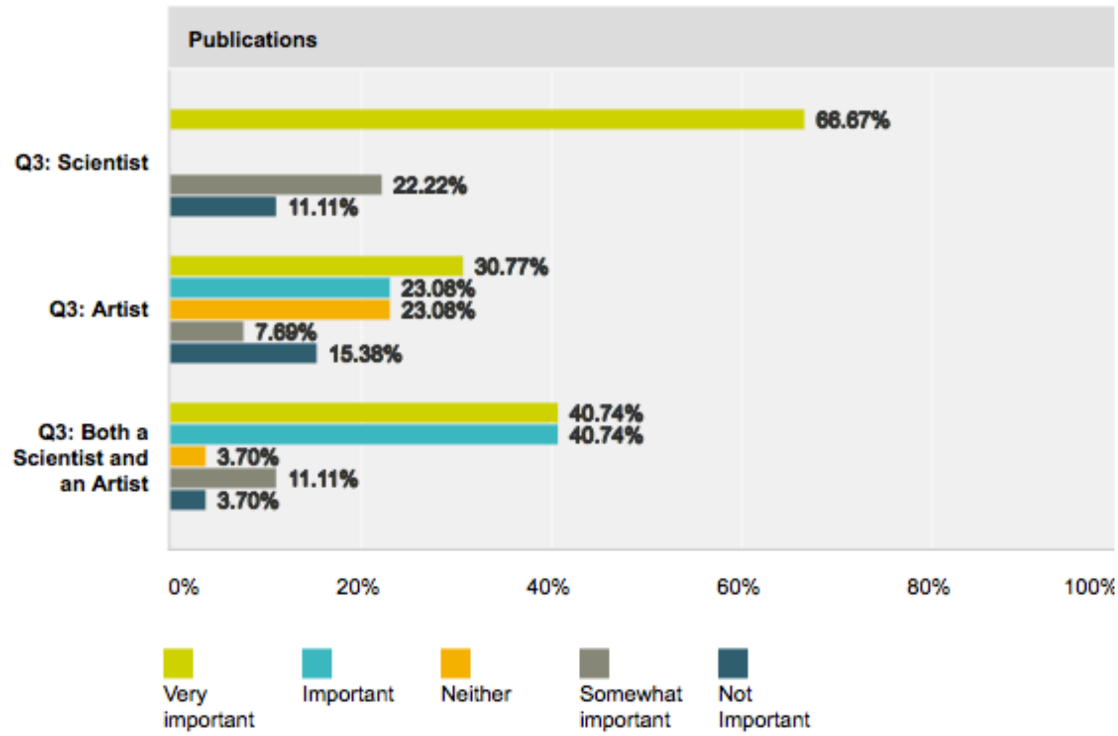
Patents
Q3: Scientist
11.11%
11.11%
77.78%
Q3: Artist
7.69%
7.69%
53.85%
30.77%
Q3: Both a Scientist and an Artist
12%
28.00%
20%
40%
0%
20%
40%
60%
80%
100%
Very important
Important
Neither
Somewhat important
Not Important



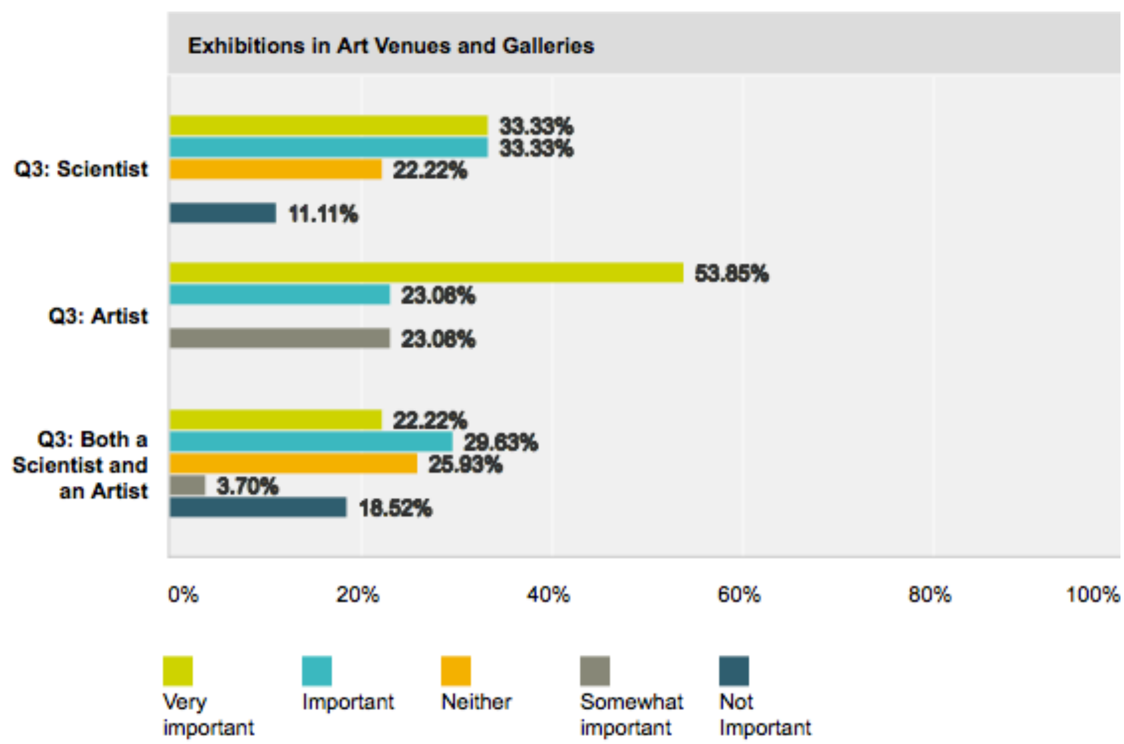
Revenue (profit)
Q3: Scientist
22.22%
22.22%
55.56%
Q3: Artist
15.38%
38.46%
15.38%
30.77%
Q3: Both a Scientist and an Artist
14.81%
18.52%
37.04%
3.70%
25.93%
0%
20%
40%
60%
80%
100%
Very important
Important
Neither
Somewhat important
Not Important


Exhibitions in Museums/Science Centers
Q3: Scientist
33.33%
44.44%
11.11%
11.11%
Q3: Artist
53.85%
23.08%
7.69%
15.38%
Q3: Both a Scientist and an Artist
25.93%
29.63%
33.33%
3.70%
7.41%
0%
20%
40%
60%
80%
100%
Very important
Important
Neither
Somewhat important
Not Important


Public outreach
Q3: Scientist
11.11%
77.78%
11.11%
Q3: Artist
61.54%
15.38%
15.38%
7.69%
Q3: Both a Scientist and an Artist
33.33%
51.85%
11.11%
3.70%
0%
20%
40%
60%
80%
100%
Very important
Important
Neither
Somewhat important
Not Important



Publications
Q3: Scientist
66.67%
22.22%
11.11%
Q3: Artist
30.77%
23.08%
23.08%
7.69%
15.38%
Q3: Both a Scientist and an Artist
40.74%
40.74%
3.70%
11.11%
3.70%
0%
20%
40%
60%
80%
100%
Very important
Important
Neither
Somewhat important
Not Important



Exhibitions in Art Venues and Galleries
Q3: Scientist
33.33%
33.33%
22.22%
11.11%
Q3: Artist
53.85%
23.08%
23.08%
Q3: Both a Scientist and an Artist
22.22%
29.63%
25.93%
3.70%
18.52%
0%
20%
40%
60%
80%
100%
Very important
Important
Neither
Somewhat important
Not Important

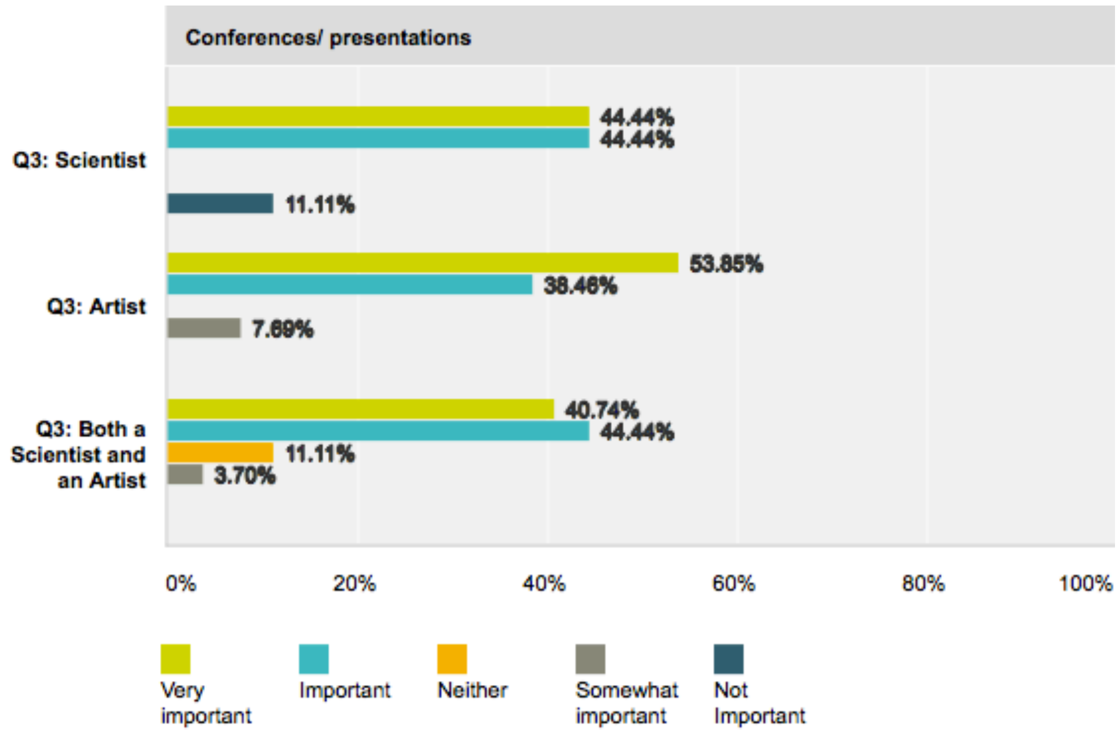


Figure 10. From your perspective, how important is each of the following outcomes of an A/S project for you? Please base your answer on the most recent collaborative A/S project you participated in.

3.2.12 Discover new opportunities:

According to our survey, scientists mostly need help with visual presentation and engaging materials. We asked specialists to share areas or fields that could benefit from scientific contribution (areas that are not currently utilizing scientist were preferred). Among those were listed;

- 3D scanning
- Art education
- Art history
- Cinema and Film
- Extremely high resolution photography
- Interactive installation art
- Media and News
- Movement learning and training for dance

Among fields that could benefit from artistic contribution (areas that are not currently utilizing artists) were suggested;

- Archaeology
- Biochemistry
- Climatology
- Human-robot interaction
- Meteorology
- Molecular biology
- Oceanography
- Physical rehabilitation
- Proteomics
- Segmentation and rendering of large scale imaging data
- Wildlife preservation

One might ask how specialists in various disciplines can explore new horizons of potential applications. Why schools do not educate artists and scientists about A/S applications, especially in the frontiers of science, art, research and technology? Information is key. Learn about current trends, art/science/technology labs in universities, industry and the government and how to get access to them. Be open-minded, be curious and explore new horizons that art and science can open for you.

“What is the most important advice you would give to an artist / scientist who is planning to start an A/S collaborative project?” Selected answers:

- Listen well
- Spend time together
- Communicate often
- “Keep the project proposal flexible - it will change anyway”
- Accept the possibility of failure
- Be patient
- Don't under-estimate yourself

3.3 Future directions

We plan to follow up with surveys designed to receive additional information, such as detailed feedback from specialists belonging to both A/S fields (art and science). This will enable us to collect additional information and provide more data on A/S collaborations, such as their background, profession and types of projects they work on. It is important to mention that this survey does not cover all topics concerning A/S collaborations. Other issues such as intellectual property and ownership, and how educational institutions and the industry foster and promote such collaborations will be included in our future work.

4 Case Studies

This part will cover three case studies that describe successes and failures in A/S collaborations. The case studies will illustrate how artists and scientists work together to overcome challenges. Authors, developers, instructors and team members of the three case studies, will be asked questions about goals and lessons learned. The answers to these questions will be shared with the SIGGRAPH course audience. Sections 4.1, 4.2 and 4.3 contain general information about the case studies.

4.1 Julia Sets collaborative projects by Dan Sandin

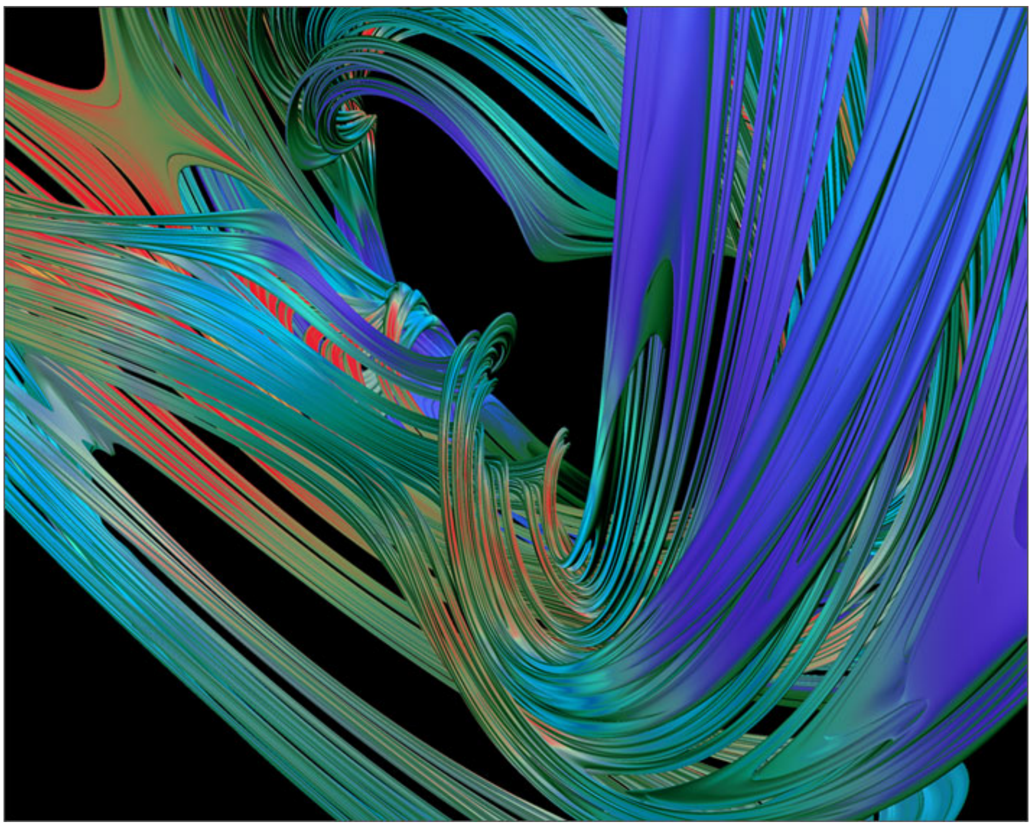
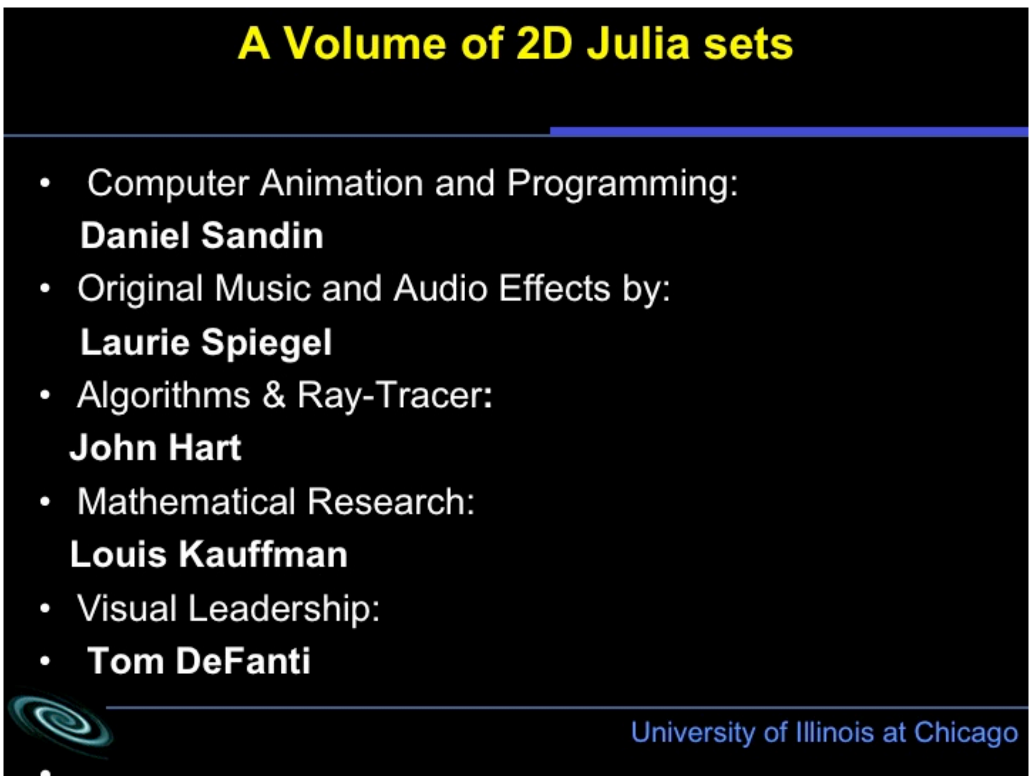


Figure 11: Close up view of Julia Set. Image provided by Dan Sandin.

The visualization of the Julia Sets is a collaborative effort between mathematician Louis Kauffman and computer graphics pioneer Dan Sandin. The collaboration started in the early 80s with renderings of two-dimensional Julia sets on pre-IBM PC computers, such as the TRS 80 laptop and the Datamax UV1 (Z-BOX). Julia sets and other fractals can exist in three and higher dimensions. Both collaborators have been interested in visualizing these three-dimensional fractals both to understand their behavior and produce interesting images and animation. The collaboration evolved during the next decades and more collaborators joined the team (scientists and artists). From this collaborative work two animations were produced; a one-minute 35mm stereo movie, "A Volume of Two-Dimensional Julia Sets" for SIGGRAPH 1990 and a super high definition (2Kx2Kx60Hz) visualization of quaternion (4D) Julia sets for Nippon Telephone and Telegraph's 50th birthday celebration. In addition, a book and a CD-ROM have been produced that describe this work. This collaboration proved useful to the collaborators in several important ways: it produced a series of artworks, new computer graphics rendering techniques, and mathematical proofs. In addition, it was an excellent test vehicle for evaluating advanced computational and network techniques.



Electronic Visualization Laboratory (EVL) Art & Science Example

- Visualization of Julia Sets
- Lou Kauffman, Dan Sandin and John Hart
- John develops new visualization technology
  - earns MS and Ph.D.
- Lou creates new theorems and gets good visualizations
- I get to make new images

Laurie Spiegel Pioneering Electronic Musician: Graduate of Shimer

Laurie Spiegel Pioneering Electronic Musician: At Bell Labs

Incomplete list of collaborative Julia set work with Lou Kauffman

- 1985 2d image “array Julia set images” Siggraph
- 1986 paper “Crossing the boundary of the Mandelbrot set”
- 1987 "The Interactive Image," Museum of Science and Industry, Chicago, IL
- 1989 John Hart generalizes Distance estimation to the quaternions
  - New computer graphics rendering method
  - New way to torture computers
  - http://www.evl.uic.edu/hypercomplex/html/book/rtqjs.pdf

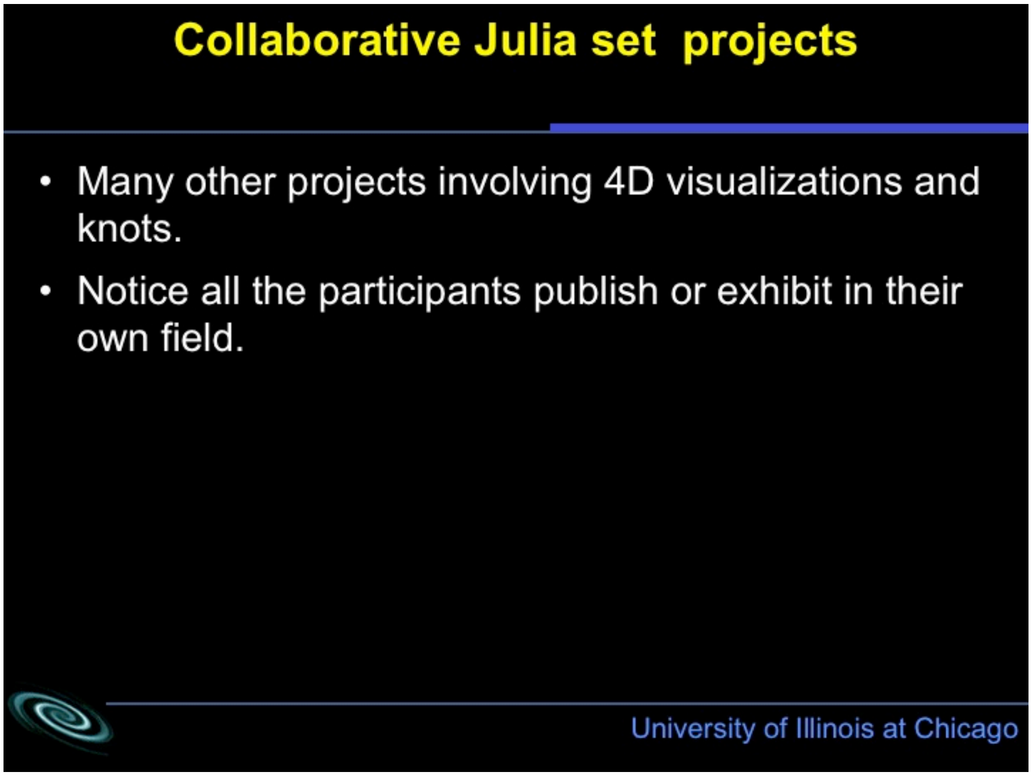
University of Illinois at Chicago

Incomplete list of collaborative Julia set projects

- 1990 animation " Volume of Julia sets" at Siggraph
- Supercomputing 95 many supercomputers work on ray tracing Julia sets
  http://www.evl.uic.edu/research/template_res_project.php3?indi=41
- 1996 Yumei Dang and Lou Kauffman prove Distance estimation is correct
  - New mathematical proof
  - http://www.evl.uic.edu/hypercomplex/html/book/book.pdf

Incomplete list of collaborative Julia set projects

- 1998 A Diamond of Quaternion Julia Sets for NTT 50^{th} birthday party
- 2002 Book and CDrom
- World Scientific Book Series On Knots and Everything : Editor – Louis Kauffman
  - Hypercomplex Iterations by Dang, Kauffman, Sandin
  - 2005 A study of 4 D Julia Sets

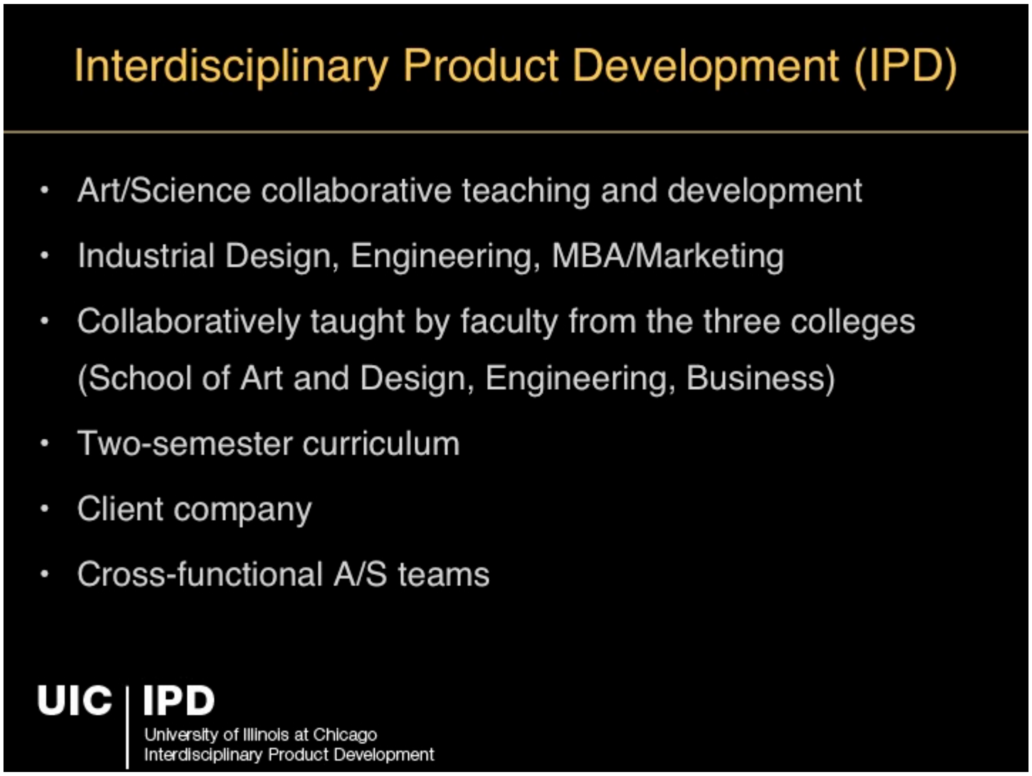


For more information, please visit: http://www.evl.uic.edu/hypercomplex/

4.2 Interdisciplinary Product Development (IPD): collaborative course in academia

Interdisciplinary Product Development (IPD) at UIC is a two-semester curriculum that integrates the latest technologies and best practices for innovative product development. The course combines Industrial Design, Engineering, and MBA/Marketing students from all three colleges to work together in cross-functional teams to research and develop new product concepts. The course focuses on the early stages of the product development process, from identifying market opportunities through initial prototyping. Eschewing the old sequential model of product development, in which a design idea originates in a business unit, is given visual form by industrial design, and then passed off to engineering, this course teaches current best practices of true integration of all three disciplines from the very earliest stages of product development.

The course is team taught by faculty from the three colleges. Each year, a corporate sponsor is recruited to serve as the client, and provides the financial support to incorporate outside resources and materials not normally available to an academic environment. Funding is used to cover the course expenses associated with paying for professionally conducted market research, team building exercises, innovation training, rapid prototyping, materials and supplies, as well as other significant course expenses. The client company, in association with the IPD faculty, also provides an interesting and challenging assignment that will result in the research, conception and development of innovative product concepts for the client.



Interdisciplinary Product Development (IPD)

- research and development of new product concepts
- integrates the latest technologies and best practices for innovative product development

UIC | IPD
University of Illinois at Chicago
Interdisciplinary Product Development

Interdisciplinary Product Development (IPD)

2012-13 partners

- Cricket Wireless
- Cobra Electronics
- Baxter Healthcare

UIC | IPD
University of Illinois at Chicago
Interdisciplinary Product Development

Interdisciplinary Product Development (IPD)

Student team makeup

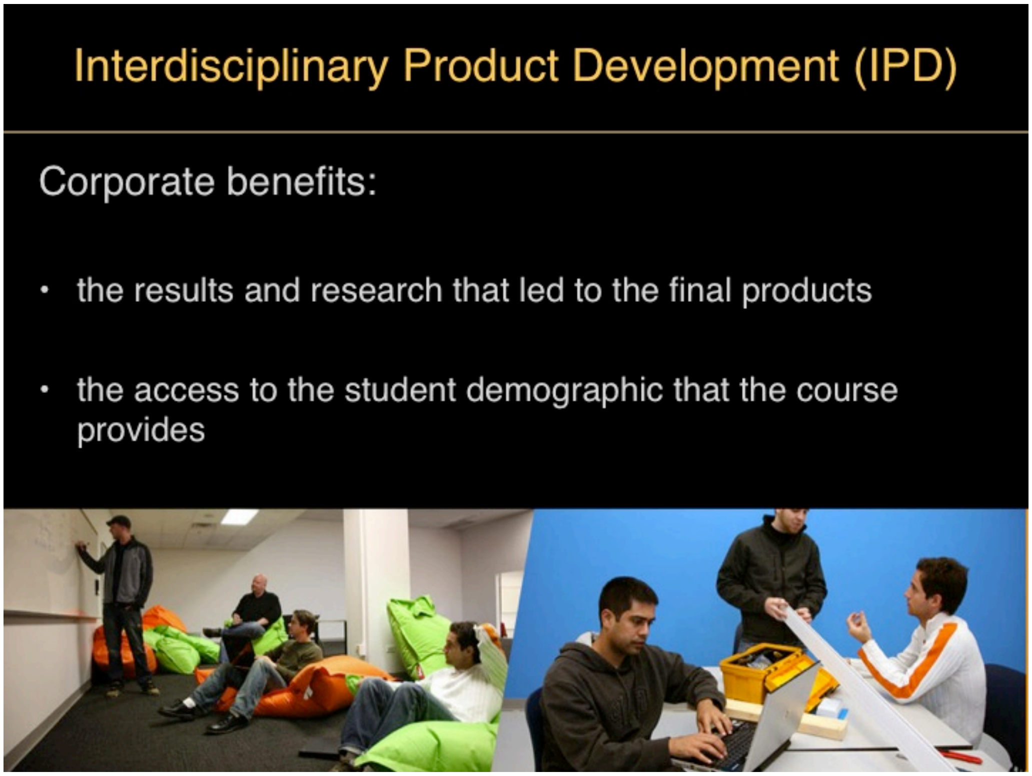
- Five A/S collaborative teams
- Engineering
- Industrial Design (School of Art an Design)
- Marketing
- MBA (Business Administration)
- MIE (Mechanical and Industrial Engineering)
- ECE (Electrical and Computer Engineering)
- other engineering disciplines

Interdisciplinary Product Development (IPD)

Client involvement

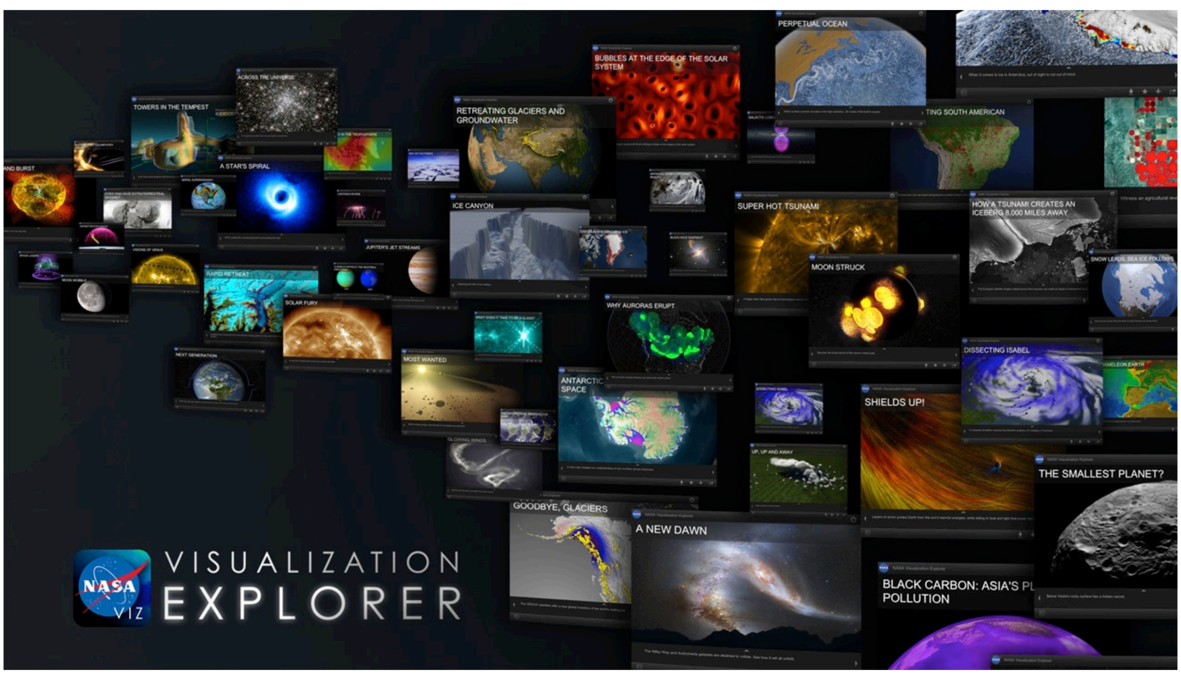
- Four presentations to the client
- Point-of-contact mentor for each student team. One person may mentor more than one student team.
- The level of involvement with the student team is up to the client/mentor
- The more involved clients are generally more satisfied with the results

UIC | IPD
University of Illinois at Chicago
Interdisciplinary Product Development



For more information, please visit: http://www.ipd.uic.edu/IPD/

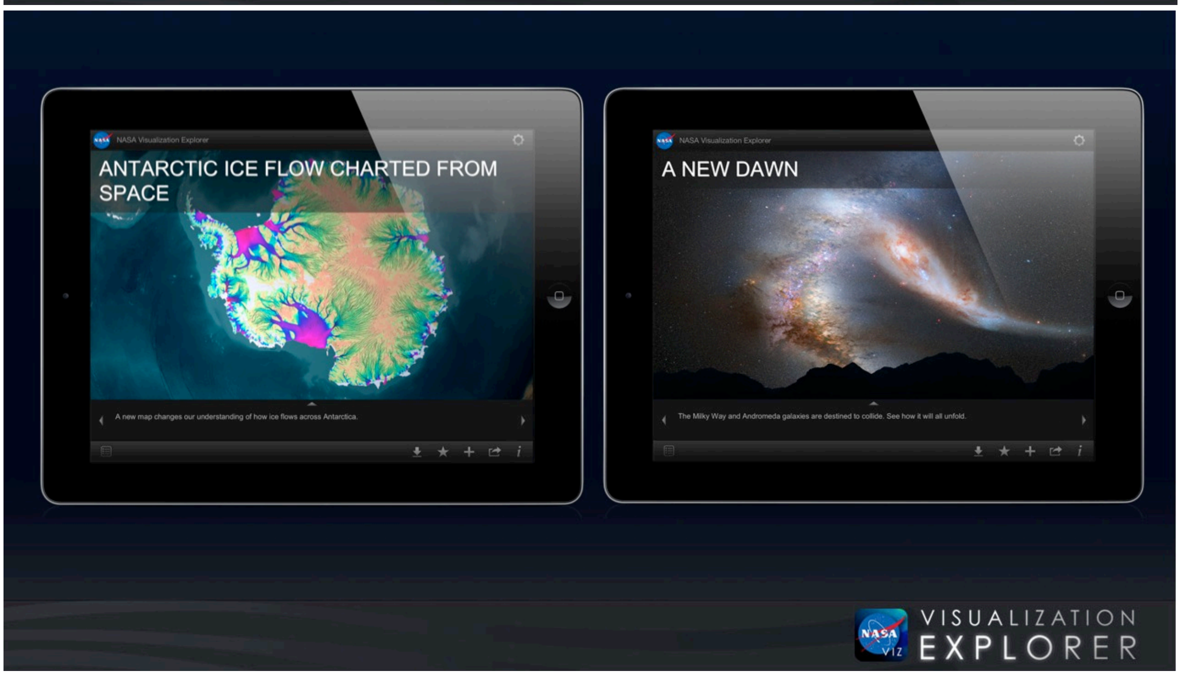
4.3 Industry example: NASA Visualization Explorer



NASA Viz: iPad app

- Free NASA iPad app available for download via iTunes *(released 07/26/11)*
- Developed for the general public
- Releases 2 data-visualization science stories per week! Total of 167 science stories have been released *(as of 02/07/13)*
- Stories cover all NASA themes: Earth, Sun, Planets, Moons and Universe
- ~ 700K unique downloads of the app *(not including updates)*
- ~ 250K hits per story for a two period
- iPhone version, Website (Desktop & Mobile) to be released Spring 2013

VISUALIZATION EXPLORER



NASA Viz: Year#2

- NASA Viz is a NASA Goddard Space Flight Center *in-house product of:*
  - Data-Visualization content (Scientific Visualization Studio & Goddard TV Multimedia group)
  - App development (Scientific Visualization Studio & NASA software developers)
  - User Interface design (Scientific Visualization Studio & NASA Goddard Interactive Developer)

VISUALIZATION EXPLORER

NASA Viz: Year#2 *(continued)*

- Back-end infrastructure (Scientific Visualization Database & Systems Experts)
- Science Writing (NASA News Team members, contributions from 14 members!)

VISUALIZATION EXPLORER

NASA Viz: Teams & Structure (Part #1)

- Visualization & Content Teams:
    - Scientific Visualization Studio (expert visualizers develop data driven animations in close collaboration with scientists)
    - Goddard TV Multimedia Studio (producers, video editors collaborate with scientists to tell stories)
    - Conceptual Image Laboratory (animators collaborate with scientists, visualizers and producers to develop non-data driven animations)

NASA VIZ VISUALIZATION EXPLORER

NASA Viz: Teams & Structure (Part #2)

- Editorial Board (science writer, producer, visualizer/project manager, image editor, visualizer with strong science background)
- App development (visualizer/project manager, software developers, producer/writer, designer)
- Web development (visualizer/project manager, database expert, developer, designer)
- Educational Research Initiative Team (visualizer/project manager, Director of Education, Einstein Fellow, Science Teachers from Maryvale Preparatory School)

NASA VIZ VISUALIZATION EXPLORER

5 References, Links, Bibliography

This section lists the references referenced in these course notes plus additional material relevant to the A/S collaboration research. The references are listed in alphabetical order with annotations. In addition we have listed selected A/S organizations and studies.

Alexa Wright, Alf Linney, The Art and Science of a Long-term Collaboration, New Constellations Conference, Museum of Contemporary Art, Sydney, 17 March 2006.

Brent MacGregor, Cybernetic serendipity revisited, Proceeding C&C '02 Proceedings of the 4th conference on Creativity & cognition ACM New York, NY, 2002

Chris Comer, SymBIOtic ART & Science: An Investigation at the Intersection of Life Sciences and the Arts, Final Report for the NSF Art and Science Workshop, NSF and the NEA, 2011, Arlington, VA, published on Jan 7th, 2012.

Dan Sandin
http://www.evl.uic.edu/dan/

DigiArts, UNESCO Knowledge Portal, a reference website on art, science and technology.
http://portal.unesco.org/culture/en/ev.php-URL_ID=1391&URL_DO=DO_TOPIC&URL_SECTION=201.html

Edward A. Shanken, Artists in Industry and the Academy: Collaborative Research, Interdisciplinary Scholarship and the Creation and Interpretation of Hybrid Forms, Leonardo 38:5, 2005, p.415-18.

Interdisciplinary Product Development (IPD), UIC
http://www.ipd.uic.edu/IPD/

List of Fields of respondents that participated in the survey (Note: the fields are listed as they were provided and described by the specialists)

- Art
- Astronomy
- Biomedical communications

- Communication
- Computational art
- Computer generated images
- Computer graphics
- Computer science
- Cultural anthropology
- Dance rehabilitation
- Design
- Digital media
- Education and outreach
- Electronic visualization
- Fine artist
- HCI
- Human machine interface
- Human-computer interaction
- Immersive arts
- Industrial design
- Information systems
- Interaction design
- Interactive art and animation
- Interactive media
- Learning sciences
- New media
- New media arts
- Physical science; earth science
- Physics
- Scientific research
- Software developer
- Virtual reality
- Visual arts
- Visual technology
- Visualization
- VR HCI
- Computer science, visual/performance art
- Metalwork, computer design
- Photography, video, new media installation

Michael J. Moravcsik, Scientists and Artists: Motivations, Aspirations, Approaches

and Accomplishments, Leonardo, Vol. 7, pp. 255-259, Pergamon Press, Britain, 1974.

NASA Visualization Explorer for the iPad - Credits. NASA SVS, n. d. Web. 12 February 2013, http://svs.gsfc.nasa.gov/nasaviz/credits.html

Roger Malina, Art Science Radar
http://malina.diatrope.com/category/art-science-radar-2/

Synapse™ supported by Australian Network for Art & Technology (ANAT)
http://www.synapse.net.au/index.php

The STEM to STEAM Briefing, Rhode Island School of Design, September 2011, http://stemtosteam.org/

The network for Sciences, Engineering, Arts and Design (SEAD) Working Group on White Papers issued by the NSF NSEAD workshop at MICA, chaired by Roger F Malina, ATEC, UT Dallas and co chaired by Carol Strohecker, Center for Design Innovation, University of North Carolina system and an international steering committee.
http://seadnetwork.wordpress.com/about/

The UCLA Art|Sci Center, dedicated to pursuing and promoting the evolving "Third Culture" by facilitating the infinite potential of collaborations between (media) arts and (bio/nano) sciences.
http://artsci.ucla.edu/?q=about