

Ideas Lab

**Promoting Interdisciplinary Agendas
through Facilitated Workshops:
Findings from Four National Science
Foundation Ideas Labs**



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Promoting Interdisciplinary Agendas through Facilitated Workshops: Findings from Four National Science Foundation Ideas Labs

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American Society for Engineering Education
1818 N Street NW, Suite 600
Washington, DC 20036

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Dr. Brian Yoder, Director of Assessment, Evaluation, and Institutional Research (AEIR) at ASEE, oversaw the research design and data collection, and wrote the final report. Rossen Tsanov, a Senior Research Associate, led the data collection, coding, and analysis, and contributed to the writing of the final report. Julia O'Donnell, a Research Analyst at ASEE, contributed to the coding of data, while Yessica Yang Choy, a Research Analyst, took part in the analysis of data and report writing. The following ASEE staff members also contributed: Editorial Director, Mark Matthews, edited the final report; Art and Production Director, Nicola Nittoli, and team members Michelle Bersabal and Francis Igot designed this publication.

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EXECUTIVE SUMMARY

Much of the literature on interdisciplinary research and collaboration has focused on how academic institutions support, promote, and manage interdisciplinary research. Although organizations that fund interdisciplinary research play an important role in promoting and advancing interdisciplinary research agendas, little research or theory has focused on how funding organizations can promote interdisciplinary endeavors by hosting meetings to generate interdisciplinary proposals. The American Society for Engineering Education (ASEE) Department of Assessment, Evaluation, and Institutional Research (AEIR) sought to fill this gap in the literature by researching four Ideas Labs interdisciplinary workshops. Each workshop convened academics from different disciplines to support the development and implementation of creative and innovative program ideas that have the potential to transform research paradigms and/or solve intractable problems.

This report documents the interdisciplinary meeting methodology and describes daily activities and meeting processes of awareness and discovery; problem definition; ideation; and proposal development that contribute to scaling innovative ideas and developing tangible proposals. AEIR researchers used participatory naturalist observation, participant focus groups, key informant interviews, and post-meeting surveys to identify barriers to interdisciplinary collaboration that arose during the workshops, learn how those barriers were overcome, and understand the interdisciplinary group dynamics that led to successfully funded proposals.

AEIR researchers found that barriers to interdisciplinary collaboration were mitigated largely through the participant selection process, which favored those with a propensity for interdisciplinary collaboration, and through activities built into the Ideas Lab meeting process. One example of a successful activity was the “Jargon Wall,” a space where participants could explain or spell out discipline-specific vocabulary and acronyms for the benefit of those unfamiliar with the terms. Researchers also noted that the Ideas Lab meetings focused on system-level changes rather than a research topic. This focus lessened the centrality of discipline at the meetings and increased the importance of knowledge gained through professional and personal activities. We refer to prior knowledge as a cognitive frame, which can encompass professional and personal experience as well as disciplinary thinking. Our study found that, far from being an impediment to innovation and interdisciplinary collaboration, cognitive frames served to leverage participants’ prior knowledge and expertise in new and novel ways. As a result, cognitive frames proved to be a major contributor to group dynamics and the successful development of proposals, a finding that will be discussed further in later sections of this report.

A pivotal moment occurred at the mid-point of the meetings, when a National Science Foundation program officer delivered a presentation on existing and forthcoming NSF funding streams that aligned with the meeting topic and to which teams could apply in the future. To a significant extent, this presentation determined the scope of ideas and the proposal development process and outcome. Participants became less intent on innovation and focused more on tangible and fundable proposals. Among factors that made a difference in whether or not a proposal would later receive funding, one was team size, AEIR researchers found; those that received funding were relatively small, with three to five members. Another factor was the ability of successful teams to articulate the contribution of team members’ cognitive frames to the proposal.

We tracked the development of two proposals that were funded.

In the summary and conclusion section, we offer suggestions of what funding organizations should consider in planning interdisciplinary meetings and workshops. These suggestions involve recruitment of multidisciplinary participants, weighing the scope and degree of innovation sought, and deciding whether the innovation is needed to change systems or to resolve technical problems. We also point out additional areas of research that would explore both how interdisciplinary workshops and meetings can contribute to novel proposal ideas, and potentially more effective ways to solicit and fund innovative proposals. One area of additional data collection and research suggested is to track Ideas Lab cohorts one to three years after attending a workshop in order to measure its lasting impact.



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BACKGROUND

The past 15 years have seen an increase in interdisciplinary, multi-disciplinary, and transdisciplinary research as academics and policymakers recognized that important ideas and discoveries often spring from collaboration among varied experts and that major challenges confronting the nation and the world demand solutions that transcend a single field. For example, cancer research, once the purview of biologists and clinicians, now engages physicists, engineers, chemists, applied mathematicians, and materials scientists (NSF, 2016).

How these collaborations develop is important to understand, particularly for funding agencies intent on making productive use of interdisciplinary research dollars. Having scientists of different fields working in close proximity to each other, able to exchange ideas, is widely credited as a source of the innovation and discovery that emerged from the legendary Bell Labs. The same principle is a hallmark of such major research incubators as the Institute for Integrative Cancer Research at the Massachusetts Institute of Technology. As multi-disciplinary research centers have developed and expanded, scholars have produced a growing body of literature on the best ways to operate them and on the career implications for researchers who join interdisciplinary projects.

A relatively inexpensive way to foster interdisciplinary collaboration is to host meetings of scientists and engineers from various fields who discuss a specific research problem. However, relatively little research has gone into how to derive successful results from such meetings.



LITERATURE REVIEW - INTERDISCIPLINARY RESEARCH

While interdisciplinary research (IDR) has been conducted for many years, the last 15 years have seen it emerge as a field in its own right and a topic for study. New programs have been spawned in the belief that IDR and multi-disciplinary research can facilitate advances in knowledge and produce solutions that would elude researchers operating within traditional disciplinary frameworks (Rhoten and Parker 2004). Some theorists predict that IDR will contribute to “leaps in scientific progress and greater economic and social benefits to society” (Sá, 2008, pg. 237).

IDR requires identification of a common problem (Pickett, Burch & Grove, 1999). Success is more likely when the research is applied and strategic, addressing a real-world situation. Examples of interdisciplinary research are found more often in strategic disciplines like medicine, human geography, and informatics than in basic disciplines like mathematics, physics, or chemistry (Van Rijnsoever and Hessels, 2011). Government and industrial laboratories are held up as examples of organizations that successfully execute interdisciplinary research given the applied nature of the problems they address and the solutions-oriented research activities they pursue (Metzger and Zare, 1999).

What is Interdisciplinary Research, as Compared to Multi-disciplinary Research and Transdisciplinary Research?

The distinctions among interdisciplinary research, multi-disciplinary research, and transdisciplinary research are open to debate. Of the three, our review of literature found interdisciplinary research to be the most widely discussed and clearly conceptualized. The term interdisciplinary research is often used in the context of researchers from different disciplines contributing their techniques, tools, perspectives, concepts, and theories in a joint effort to solve a common problem.

Definitions of Research that Crosses Disciplinary Lines

Multidisciplinary Research	Researchers from different disciplines work collaboratively on a common research problem, but work in parallel, within their respective disciplines (McGregor, 2004). Example - a panel of academics from biology, oceanography, demography, political science, and economics creating a report that looks at the impact of global warming written from the different disciplinary perspectives.
Transdisciplinary Research	Crossing of disciplinary boundaries to create new approaches to creating knowledge (Aboelela, et. al., 2007; Huutoniemi, et al., 2010). The term transdisciplinary research is often used in the context of researchers from different disciplines collaborating to conceptualize and create a new discipline; for example, bio-informatics.
Interdisciplinary Research	Researchers from different disciplines integrate information, data, techniques, concepts and/or theories from two or more disciplines. The term interdisciplinary research is often used in the context of solving problems whose solutions go beyond the scope of a single discipline or areas of research (National Academy of Sciences, 2005).

For the purposes of this study, we will use the term “interdisciplinary research” and draw on the definition cited by National Science Foundation (2016) that was developed by a panel at the National Academy of Sciences (2005):

“Interdisciplinary research is a mode of research by teams or individuals that integrates information, data, techniques, tools, perspectives, concepts, and/or theories from two or more disciplines or bodies of specialized knowledge to advance fundamental understanding or to solve problems whose solutions are beyond the scope of a single discipline or area of research practice.”

Based on this definition of interdisciplinary research, we expect that members of Ideas Lab meetings will discover ways to define common problems around the meeting topics, and to craft novel and new approaches to these problems because of their exposure to data, techniques, tools, perspectives, concepts, and theories from other disciplines.

Barriers to Interdisciplinary Research and Collaboration from the Literature Review

A recurring theme in the literature on interdisciplinary research (IDR) and collaboration is that each discipline determines much of the way its researchers look at the world and approach problems. Disciplines differ in methodology and in their views as to what constitutes knowledge and what sort of knowledge is possible. Practitioners may even differ in styles of behavior and political affiliation. Each discipline, in short, has its own culture, reflected in its practitioners' distinct attitudes, habits, and manners (Bauer, H. H. 1990). A discipline's culture is inherently linked to its practitioners and inseparable from them (Bauer, H. H. (1990). The customs, common values, understandings, and relationships that define a discipline's culture tend to slow down communication and cooperation with practitioners of other disciplines. Words and terms can take on different meanings depending on one's discipline. While a researcher from one discipline may apply a single exact definition of a term, another researcher may define it based on the context in which it was used. Collaborating mathematicians and biologists, for example, may have to work hard to agree on such concepts as "proof" and "precision" (NAS, 2005).

Differences of culture, vocabulary, and modes of inquiry frequently make it difficult for IDR researchers to communicate with and understand each other, undermining their joint enterprise. Investing in a common grasp of disciplinary methods and jargon, or "translating" such methods and jargon, poses a challenge for experienced researchers who communicate with great fluency and literacy within their own disciplines. In the words of Caruso and Rhoten, "researchers must be hyper vigilant about language, taking extra effort to explain themselves rather than expecting their extra-disciplinary colleagues to translate between the various shorthands of lingo and metaphor, shared scholarly references and assumptions" (Caruso and Rhoten, 2001).

Oftentimes, cultural barriers and the lack of a common understanding and vocabulary prevent IDR researchers from reaching consensus on a common problem or topic. Finding a topic that transcends disciplines — as opposed to transferring an accepted problem from an already established discipline — is considered a prerequisite for the success of any interdisciplinary endeavor. Yet, finding a common topic remains a key barrier to IDR. Consensus can be reached in a number of ways, such as mutual recognition of similarities between questions and discovery of shared themes between disciplines. Overwhelmingly, failure comes from choosing too broad a topic (Caruso and Rhoten, 2001; Campbell, 2005).

Roadblocks to collaborative research may also arise from institutional biases, differences over how to define and achieve success, access to data and publications from other disciplines, competition and turf protection, and a distrust of individuals outside one's own discipline. In addition, researchers sometimes enter into agreements with an inadequate understanding of the management, internal politics, decision-making structures, and even fundamental interests of their partners, resulting in a lack of trust, slow decision-making, and insufficient resources (Caruso and Rhoten, 2001; NRC, 1999).

Management of interdisciplinary efforts poses further challenges. The success of an interdisciplinary project can be made or broken by the availability of funding. Usually, colleges and funding agencies have limited funding for IDR. Campus reward mechanisms also come into play; a reluctance to recognize interdisciplinary endeavors as equivalent to research in a single discipline can present a real impediment to IDR (van Rijnsoever and Hessels, 2011; Maglaughlin, Sonnenwald, 2005). In addition, interdisciplinary research tends to take longer, given the more complicated arrangements involving staff, infrastructure, and equipment. It also takes time for researchers from different disciplines to create common definitions and approaches so that they can work together. As a result, IDR often exceeds the institutional attention span of most funding agencies and decision makers. Finally, difficulties can arise over publishing and intellectual property (Caruso and Rhoten, 2001; NAS, , 2005; Campbell, 2005, NCR, 1999).

Cross-disciplinary collaboration can also be impeded by the organization of universities around departments and disciplines, with their different cultures, policies, procedures, and restrictions. (Nielsen-Pincus et. al, 2007). The European Research and Advisory Board (EURAB) found that barriers to IDR are highest where the traditional one-department, one-discipline structure is also reflected in the structures of research funding bodies. Specific challenges include the difficulty of creating new interdisciplinary programs by using established one-discipline funding systems, the weakness of multidisciplinary career structures, the lack of established interdisciplinary scientific journals, and education systems that are not geared toward producing multidisciplinary graduates and postgraduates (NAS, 2005). In academia, career advancement is disciplinary based (Campbell, 2005) and faculty promotion and tenure processes undervalue collaborative and interdisciplinary work (Sá, 2008). Rhoten and Parker (2004) found that early career academics are the most apt to pursue interdisciplinary research, since they have less intellectual commitment to a particular discipline. But in doing so they assume more risk, since it will likely take them longer to become professionally established.

Power differentials within a research team comprising individuals at different career stages, with one as project leader, need to be acknowledged, minimized, and managed, or else they can undermine interdisciplinary collaborations (Campbell, 2005).

In a 2005 conference paper based on a comprehensive empirical study on factors affecting interdisciplinary scientific research collaboration that combines data from interviews and longitudinal files, Maglaughlin and Sonnenwald describe four factors that can act both as facilitators or as barriers to IDR, and which summarize barriers to IDR in the literature well (Maglaughlin, Sonnenwald, 2005):

Table 1. Factors found to impact interdisciplinary scientific research

Personal factors characterize collaborators' preferences, abilities, feelings, and perceptions	Resource factors highlight resources needed by scientists to support interdisciplinary science	Motivation factors factors that appear to motivate interdisciplinary collaboration are:	Common Ground factors encompass cognitive, physical and political common ground. All three play a role in scientific collaboration
<ul style="list-style-type: none"> • Expertise • Social networks • Trust • Personal compatibility • Common professional traits 	<ul style="list-style-type: none"> • Support from funding agencies • Support from scientists' institutions • Literature • Scientific publishing • Students • Time 	<ul style="list-style-type: none"> • Learning & teaching • New discoveries • Fun • External rewards 	<ul style="list-style-type: none"> • Physical proximity • Research organizations • Disciplinary bias • Discipline-specific languages • Bridges

Funding Organizations and Interdisciplinary Research

Research literature on how funding organizations can promote interdisciplinary collaboration is comparatively sparse. Among the most thorough discussions of the challenges and opportunities for funding organizations is a chapter entitled "How Funding Organizations Can Facilitate Interdisciplinary Research" in the 2004 National Academies report, "Facilitating Interdisciplinary Research." These are some of its recommendations:

- Develop funding programs specifically designed for interdisciplinary research by focusing on research around problems rather than disciplines.
- Provide seed-funding opportunities for proof-of-concept work that allows researchers in different disciplines to develop joint research plans and perform initial data collection.
- Fund programs of sufficient duration to allow for team-building and integration of research efforts.
- Develop criteria to ensure that proposals are truly interdisciplinary and not merely adding disciplinary participants.
- Designate funds for interdisciplinary research meetings that encourage interaction between researchers in different disciplines so they can learn about research in other fields and find potential collaborators.



PURPOSE OF STUDY

While several studies have been conducted on interdisciplinary research and multi-disciplinary research at universities, and articles have been written about multi-disciplinary research centers and academics' experience with interdisciplinary research, not much research has focused on how funding organizations, such as foundations and government agencies that provide research grants, can contribute to interdisciplinary agendas through the hosting of interdisciplinary meetings. This report aims to help fill this gap in the literature by providing examples of meetings that aim to facilitate novel and new approaches to solving problems through interdisciplinary exchanges.

ASEE's goal for this series of Ideas Labs was to offer examples of interdisciplinary meetings that encourage interaction between researchers from different disciplines. We planned to observe whether and how individuals from different disciplines can coalesce in teams and synthesize approaches to problems that cannot be solved through a single discipline. The principal audience for the findings is funding organizations that want to initiate interdisciplinary problem-solving research.

NSF Ideas Lab Meetings

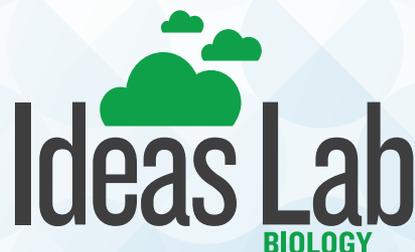
This report provides accounts of three interdisciplinary Ideas Labs hosted in the spring of 2014 by the American Society for Engineering Education. The meetings coincided with the National Science Foundation's development of the Ideas Lab concept as an interdisciplinary funding mechanism to "support development and implementation of creative and innovative program ideas that have the potential to transform research paradigms and /or solve intractable problems" (NSF, 2016). The three pilot Ideas Lab meetings were hosted in suburban Washington, D.C. on the following topics:

- NSF Ideas Lab: Geoscience - March 2 - 7, 2014 - focused on bringing together multi-disciplinary expertise in the geosciences to reform undergraduate geoscience education. The intent of the reforms was to develop essential competencies and skills for the workforce and increase access for diverse student populations;
- NSF Ideas Lab: Engineering - March 17 - 21, 2014 - focused on changing the systems in engineering education that contribute to social inequality and on efforts to broaden participation, increase diversity, and improve recruitment and retention of women, minorities, and people with disabilities;
- NSF Ideas Lab: Biology - March 31 - April 4, 2014 - focused on strategies to integrate quantitative lit-

eracy into a biology core curriculum and to study its effectiveness and/or impact to generate knowledge that will inform broader implementation.

- Meeting logistics were managed by ASEE. The sessions were facilitated by a contractor with known expertise in conducting productive meetings and in guiding the creation of interdisciplinary teams and ideas. Researchers from ASEE attended all three meetings and documented meeting processes and outcomes through note-taking, participatory naturalist observation, participant focus groups, key informant interviews, and a post-meeting survey.

Subsequently, ASEE hosted a fourth Ideas Lab from March 20 - 24, 2016 in suburban Washington, D.C. Called Geo Opportunities for Leadership in Diversity (GOLD), the meeting focused on unleashing the potential of geoscientists with interests in broadening participation to become impactful leaders within the community. With the same contractor facilitating, participants explored the design, pilot implementation, and evaluation of innovative professional development curricula. ASEE managed meeting logistics and ASEE researchers conducted a post-meeting survey to confirm some of the findings from the first three Ideas Lab meetings.



RESEARCH METHODOLOGY

ASEE's office of Assessment, Evaluation and Institutional Research (AEIR) was charged with collecting information and insights from the meetings that would advance knowledge of effective multidisciplinary collaborations and of creative approaches to problem-solving across different fields. Present throughout the 2014 Ideas Labs, AEIR researchers observed the meeting process and conducted interviews and surveys to learn how participants framed problems, shaped teams, and crafted novel solutions in the form of proposals. They took detailed notes and photographs and made audio recordings of plenaries, breakout sessions, and daily mentors' debriefs and training sessions. The team also conducted ad hoc, unstructured interviews with Ideas Labs participants and stakeholders (i.e. mentors, facilitators). Notes and photographs were dated and tagged according to the type of session or activity. Audio recordings were professionally transcribed.

Various online surveys were conducted at different times. The open-ended Ideas Lab Research Survey, administered after each of the three meetings, explored barriers to interdisciplinary research in small group settings as well as contributions made by participants from different disciplines to proposals that emerged from the meetings. A separate survey after each meeting asked participants about their experience and their level of satisfaction with the meeting and meeting-outcomes. Similar surveys were conducted with the 2016 GOLD Ideas Lab cohort to test some of the findings from previous meetings and investigate further the process of team formation and proposal development.

For the data analysis, all background documents, literature review findings, observational notes and photographs, transcribed interviews and audio recording of sessions, and data from all online surveys were uploaded into MAXQDA – a software for qualitative analysis. Two qualitative researchers then applied a combination of inductive coding for discovery and deductive coding aligned with research ideas and points of inquiry. An Inter Coder Reliability (ICR) training and testing procedure was conducted with 5% of the data at two points in time during the coding. The ICR combined mean score of agreement from the two tests was 70% for Cohen's Kappa coefficient, (MAXQDA, 2016). An in-depth qualitative analysis was conducted with MAXQDA, and emerging themes and findings from the coded data were compiled for this report. The research team also ran a member check (Carlson, 2010) with sixty-one Ideas Lab participants who completed surveys after the meeting, providing a summary of findings and posing some clarifying questions, in order to make sure that the research findings were on point and our interpretation of the data resonated with members. Six members responded and discussed findings for the final edit of the report.

AEIR's research team conducted a literature review on the topic of interdisciplinary research and collaboration, in order to put the Ideas Lab meeting methodology into context, and to see how the objectives of the meetings relate to the existing body of research and literature.

SANDPIT MEETING METHODOLOGY

Ideas Lab, which became an official National Science Foundation funding mechanism in 2014, is modeled on interdisciplinary meetings developed by the Engineering and Physical Sciences Research Council (EPSRC) in the United Kingdom called Ideas Factories, or Sandpits. The goal of Sandpits is to bring together a dynamic group of individuals with skills needed address real-world problems in new, creative and innovative ways.

As described by EPSRC (EPSRC, 2016), Sandpits are residential interactive five-day workshops that bring together a multidisciplinary mix of 20-30 participants, both active researchers and potential users of research, to “drive lateral thinking and radical approaches to address research challenges.” Participants come from a range of fields and backgrounds and are selected for the right mix of disciplines and personal attributes, like creativity, communication skills, and a willingness to take risks. The meetings are led by a director, with a group of stakeholders and subject matter experts working as mentors. Funding is usually given out at the end of a sandpit meeting. The amount varies, depending on whether it will be used for a single large study, smaller studies, networking activity, or another pursuit.

Although sandpit meetings do not follow an official agenda, since that would detract from the free-form nature of the meeting, discussions typically include these elements:

- Defining the scope of the issue.
- Agreeing on a common language and terminology among people from a very diverse range of backgrounds and disciplines.
- Sharing an understanding of the problem domain, and the expertise brought by the participants to the sandpit.
- Taking part in break-out sessions focused on the problem domain, using creative and innovative thinking techniques.
- Capturing the outputs in the form of a research project.

Knowinnovation, Inc. modified the Sandpit method for the meetings they facilitated for NSF and adopted the name Ideas Lab.

IDEAS LAB MEETING METHODOLOGY

According to Knowinnovation, Inc. contractors, selection of well-suited participants for an Ideas Lab meeting is key to the formation of teams and the development of interdisciplinary proposals. A meeting participant who does not have the proper sensibility or mind-set may not fully participate in the meeting or might even cause disruptions. We found that many of the identified characteristics of good Ideas Lab participants overlap with characteristics of individuals who are adept at interdisciplinary collaboration (Caruso, D. and Rhoten, D., 2001). The characteristics of well-suited Ideas Lab meeting participants include:

- Intellectual curiosity and a willingness to explore new aspects of the meeting topic;
- Ability to work collaboratively;
- Openness to new ideas and to new ways of thinking and working;
- Strong interest in the Ideas Lab meeting process and willingness to watch the process unfold;
- Acceptance of responsibility for their level of participation in the meeting;
- Awareness of and ability to manage ego;
- Ability to contribute constructively to their own team and other teams;
- Satisfaction with having participated in an Ideas Lab meeting, regardless of funding.

Roles, agendas, process, activities

Ideas Lab is an intensive, interactive, five- to six-day residential workshop designed to produce radically innovative research project proposals. Between 20 and 30 participants with diverse backgrounds and experience in disciplines relevant to the meeting topic come together in a creative, free-thinking environment, away from their everyday routines and responsibilities to immerse themselves deeply in a collaborative process around an important challenge. Prior to the meeting, selected participants engage in shared readings and/or brief on-line meetings to create a shared understanding of the meeting topic. In the case of the first three pilot meetings, the time between participant selection and the face-to-face Ideas Lab meetings was brief, and the topic of the meetings was not introduced to the participants prior to the face-to-face meetings as is normally done. Meeting face to face over the course of the week, participants work to deepen their shared understanding of the designated challenge, to redefine the problems within the challenge, and to generate novel ideas for research proposals.

The goal of Ideas Labs: Innovative proposals that are in the 'third-third' tier of ideas

The objective of Ideas Lab workshops is for emerging teams to generate radically innovative ideas and develop them into proposals that tackle the main problems around the workshop topic. As defined by the facilitators, ideas fit into three categories. The first third of ideas are not really ideas - they are memories from the past or habitual current experiences. The second third are ideas that, although new to the group or an individual, have actually been thought of by somebody else. The final third are the innovative and radical ideas that break new ground and stretch existing boundaries. Developing those third-third-tier ideas is the purpose of Ideas Lab.

The criterion used to evaluate an idea for the third-third tier is whether it's risky and cutting edge with a serious Wow-factor. Would it be unlikely for the idea to get funded through traditional mechanisms? The difference between Ideas Lab proposals and those responding to a regular call for proposals is the level of risk. Ideas Lab proposals are a bit wilder and more imaginative. The participants who present these proposals often agree that they would never have come up with such novel and risky ideas without the mix of people and expertise brought together by an Ideas Lab. A third-third-tier idea is also inherently multidisciplinary or at least is one that blends diverse backgrounds and experiences within a discipline.

Funding

A typical Ideas Lab workshop is expected to produce between five to 10 proposals. Event organizers can choose to fund them or not, depending on merit and how intriguing they are. In the case of Sandpits, funding is usually announced at the end of the meeting. Participants understand beforehand that funding will be available for novel proposals. At the start of the 2014 NSF Ideas Lab pilot workshops, there was no assurance that any proposals would be funded. Instead, NSF waited until midway through the workshop to present funding options and potential future opportunities based on existing programs and opportunities.

Participant selection

Applicants seeking to join an Ideas Lab meeting write a brief essay in which they describe their interest and expertise in the topic as well as personal attributes, such as willingness to work on a team, communication skills, and willingness to take risks, that will enhance the

meeting. Participants are chosen by NSF. For the Ideas Labs we observed, the contractor hired an organizational psychologist, who had previously helped pick participants for British Sandpit meetings, to review applications and make recommendations to NSF based on personality characteristics revealed in the essays. The psychologist looked for researchers who are adept at interdisciplinary collaboration, knowledgeable about their own discipline, respectful of differences in research and “knowing” among different disciplines, able to communicate well, and willing to understand a problem from another’s point of view.

Beyond a capacity to engage in interdisciplinary collaboration, participants must also be able to withstand a demanding, competitive, and stressful workshop experience. They are asked to meet and connect quickly with new people from different fields and backgrounds, then quickly form teams and solve problems together. An individual’s ideas might not be well received by the group. Solutions proposed by one team might fall short in competition with those from other teams.

Participants

Depending on the Ideas Lab subject, a diverse range of academics might be invited to apply: physical scientists, engineers, biologists and chemists, mathematicians, statisticians, physicists, computer scientists, social scientists, architects and artists, musicians, medical specialists. The more multidisciplinary the participants, the more likely it is that novel and eccentric ideas could emerge. When participants have to translate the jargon they’re accustomed to so others can understand it, new

connections occur that often move discussions toward novelty and innovation.

Director

The Director acts as the leader of the event. S/he is appointed by the funders and serves to guide the process from a scientific perspective. The Director sets the stage, clarifying the vision up front and steering the event to stay aligned with that vision over the course of the week. During the workshop, the Director will work closely with the mentors, guiding them as they interact with the participants. After the workshop, the director remains engaged, reviewing the final proposals and monitoring the development of the projects.

Mentors

The mentors are analogous to peer reviewers but with a much more creative role. At the start of the event, their job is to encourage new ideas by asking questions, highlighting ideas that seem exciting, and making connections between participants and also with the wider body of knowledge. The mentors’ role changes towards the end of the workshop, when they have to adopt a more critical perspective in order for them to be able to assist in the development of innovative, third-third proposals.

Mentors work with the Director to provide objective advice and input to the participants, but they also potentially have a role in selecting the participants, and in commenting on the research projects arising from Ideas Lab, with the overall aim to ensure that the workshop leads to high-quality innovative research.



Facilitators

The facilitators (the contractor) work closely with the director, mentors, and funders in preparing the schedule. While the Director and mentors are responsible for the content of Ideas Labs, the facilitators are responsible for the process. During the workshop itself, they will take the lead on explaining the process and directing the activities. In addition, they will facilitate smaller groups as needed and in general keep an eye on how the workshop is advancing, in terms of the process and how the participants are feeling and reacting. The facilitation team has to be extremely flexible, often making decisions very quickly to alter the agenda in response to the progress of the group and the observations of the mentors and the director.

Organizers/Funders

The prospect of funding at the end of the event (or possibly in the future, as was the case with NSF's Ideas Labs) is part of what generates energy and momentum in an Ideas Lab. It's important and useful for one or two staff members from the hosting and funding organization (which can be one and the same or a partnership) to be present, particularly on the first day, to help with administration and logistics. Once the meeting is under way, it's helpful to have the funding organization represented to track the development of projects and answer questions about criteria for funding or how funding could potentially be made available.

Stakeholders

The best way to be sure that participants get a full grasp of the context of a challenge is to invite people with experience of the issue – so-called stakeholders – to address the group. Stakeholders may be experts in fields related to the Ideas Lab topic, lobbyists, or representatives from government, industry, or citizen/user groups. Depending on the nature of the workshop, mentors or even funders might also be stakeholders. In other cases, stakeholders are invited to spend one day at the workshop to give a presentation and answer participants' questions.

The role of the stakeholder is to stimulate thinking among the participants by helping them to understand the nature of the problem or a piece of it, apprise them of current thinking on the challenge and the state of research, or challenge them to think of possible solutions and test their assumptions. The purpose of a stakeholder's presentation is not to persuade participants to see things his or her way, but to provoke different kinds of questions about how the problem might be approached.

Guest Speakers/Provocateurs

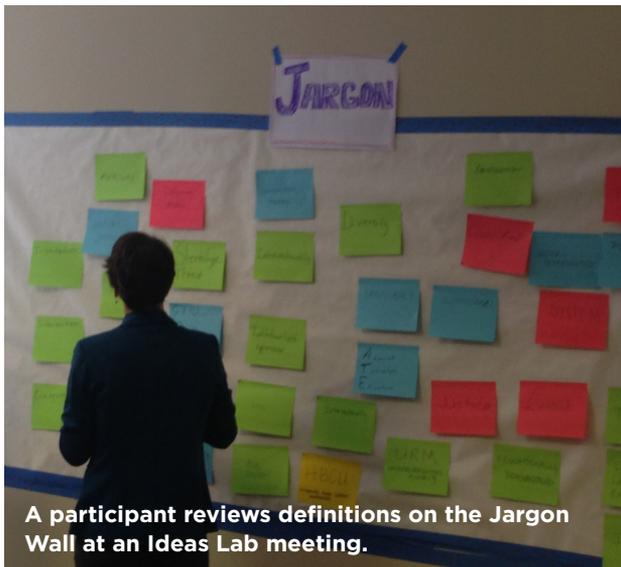
While it is important to have stakeholders share information with the participants, additional speakers may be invited. Depending on the nature of the event, it can be useful to have a speaker or activity with little connection to the problem help participants draw analogies or make connections that stimulate their thinking. Drawing on speakers far removed from the field and the workshop can provide a pleasant break from the subject at hand and inspire participants to think and use information differently and pose new questions. Guest speakers can be entertaining and light, or provocative and intense. Either way, they pull the participants into a different universe, one that might lead to novel ideas.

RESEARCH FINDINGS

THE ROLE OF DISCIPLINES

Discipline was not seen as much of a barrier. However, the mix of participants did not appear optimal given the system-level problems the Ideas Labs were intended to address. A key question in ASEE's study of the 2014 pilot Ideas Lab meetings was how a participant's discipline affected his or her interaction with participants from other disciplines and approach to the topic. We wanted to learn what kinds of challenges and barriers disciplinary differences could create in an Ideas Lab setting and how participants overcame those barriers. We found that a participant's discipline was not much of a factor at the meetings and did not create a serious barrier for participants. Instead, in surveys, interviews, and observations, barriers were more often attributed to personal characteristics, such as a participant not being a "team player," insisting on a particular point of view, or trying to dominate an activity or discussion. Such behavior disrupted the meeting process and sometimes sowed discord among groups of participants. Participants reacted by avoiding someone seen as troublesome and at times discouraging him or her from joining their group. On-going attention by the facilitators to prevent disruptions minimized the overall impact of such behavior on the meetings.

Likewise, post-meeting surveys showed that differences in discipline-specific vocabulary were not seen as a barrier, although they did slow down some discussions as participants struggled to understand one another. Vocabulary differences posed a problem most often when participants represented a greater diversity of disciplines, as was the case in the engineering Ideas Lab meeting. Participants worked to overcome vocabulary differences by listening to each other carefully and by posting definitions on a "Jargon Wall," a device that helped participants understand important discipline-specific terms and acronyms.



A participant reviews definitions on the Jargon Wall at an Ideas Lab meeting.

One reason disciplinary barriers did not loom large is that the meeting topics dealt with system-level problems. Disciplinary knowledge was relevant but not central to finding solutions to these problems. The geosciences Ideas Lab focused on reforming undergraduate geoscience education so as to develop essential competencies and skills for the workforce and increase access for diverse student populations; the engineering Ideas Lab focused on changing systems in engineering education that contribute to social inequality and on efforts to broaden participation, increase diversity, and improve recruitment and retention of women, minorities, and people with disabilities; and the biology Ideas Lab focused on strategies to integrate quantitative literacy into a biology core curriculum and broaden its implementation. Far from seeing disciplinary differences as barriers, participants noted that it would be helpful to have more diverse perspectives from different parts of the "systems" in question.

Most of the participants in the geosciences Ideas Lab, the first pilot Ideas Lab ASEE hosted, were early- to mid-career faculty from geoscience-related disciplines, including geoscience, geology, paleontology, atmospheric science, and oceanography. We found that factors other than discipline, such as place of employment or professional experience, had a stronger influence on the contribution participants made to a proposal. For example, an early-career environmental geologist at a community college would likely have limited research experience but could offer a valuable contribution based on his or her teaching experience. One participant pointed out that the formal science educators and the informal science educators were self-selected and divided into two different groups at the end of the geoscience meeting, a selection not based on discipline but a professional division. We asked if there were any disciplines missing from the meeting. Participants noted that it would be good to have employers, education researchers, and more representatives from two-year colleges, minority serving institutions, tribal colleges, and historically black colleges and universities at the meeting. These suggestions were not based on discipline but on a realization that various parts of the overall "system" – industry, community members, provosts, and students – could help solve the problem selected as the meeting topic but were not present.

The second Ideas Lab meeting ASEE hosted focused on changing the systems in engineering education that contribute to social inequality and on efforts to broaden participation, increase diversity, and improve recruitment and retention of women, minorities, and people with disabilities. This meeting had the greatest diversity of disciplines represented, with a third of the participants from various engineering disciplines, a third

from social sciences, and a third from a variety of other related disciplines like education, art, design, visualization, organizational communication and social change. Of the three pilot Ideas Lab meetings, this meeting produced the most challenges from vocabulary differences, according to post-meeting surveys. However, participants overcame these challenges by listening to each other carefully and posting disciplinary-specific definitions on the “Jargon Wall.” The challenges with differences in disciplinary vocabulary were not seen as a barrier, but more of an advantage for viewing the problem from a different perspective, an investment in time for a better meeting outcome.

The third Ideas Lab meeting we hosted focused on strategies to integrate quantitative literacy into a biology core curriculum and to study its effectiveness and/or impact to generate knowledge that will inform broader implementation. The majority of participants were from a biological discipline, with a few from other fields like applied mathematics, educational leadership, interdisciplinary studies (biology and physics) and STEM education measurement. Discipline was not seen as a big barrier to participation in the meeting by the meeting participants, according to a post-meeting survey. Once again, they cited a few examples of challenges related to vocabulary differences based on discipline but also issues related to the personality of participants.

THE ROLE OF FUNDING

During a typical Sandpit meeting, funding for projects developed during the meeting is awarded on the last day of the meeting by the meeting organizer/funder. Normally, a range of funds that could be awarded are specified prior to the meeting and the organizer/funder is under no obligation to award funds if the meeting does not produce a project they wish to fund. The pilot Ideas Lab meetings deviated from the Sandpit approach by not explicitly providing details about how funding would be provided for project ideas prior to the meeting and then by presenting funding options mid-week. For each meeting, the funding options were different, but required a proposal to be submitted sometime after the meeting.

The prospect of research funding, once introduced, changed the character of the meeting from brainstorming to a discussion of specific proposal ideas, and changed participants’ approach to and mindset for the meeting. Prior to the announcement of funding, participants enjoyed the meeting and the interactions with others. The meeting gave participants an opportunity to think big about the meeting topic, to think creatively, and to understand the meeting topic from the perspective of others. When the National Science Founda-

tion introduced the idea of creating funded proposals at the mid-point of the meetings, participants shifted focus from thinking broadly and innovatively about the meeting topic to conceptualizing a project or a proposal they felt comfortable implementing and one that they thought might be funded by NSF. The shift was characterized by more than one participant as a “down shift.” When present and forthcoming NSF funding mechanisms that could be linked to future Ideas Lab proposals were announced, participants focused on developing fundable projects by applying their prior knowledge to the meeting topic. We will refer to prior knowledge as a cognitive frame, which can include disciplinary thinking, knowledge gained through professional activities, or knowledge gained through personal activities.

COGNITIVE FRAMES

We wanted to investigate how ideas were developed over the course of the five-day Ideas Lab meetings, how ideas were incorporated into projects to be turned into proposals, what barriers arose, and what facilitating methods allowed people from different disciplines to work together to create innovative proposals. When we observed the meetings, we noticed that participants relied on cognitive frames when developing projects to address the meeting topic. Many participants came to the meeting with project ideas that they wanted to implement, or they had a particular view or experience that shaped the way they viewed the meeting problem. We originally thought that reliance on cognitive frames would prove to be a barrier to innovation. Rather than thinking “outside the box” and coming up with wildly creative and novel solutions, people were thinking “inside a box” they already knew. But, as we analyzed the data and began looking at funded projects from the meetings and asking why the projects that came out of Ideas Labs were funded by the National Science Foundation, we realized that the cognitive frames were an important part of developing an innovative and fundable proposal. Based on post-meeting survey results, we found that the successful proposals were based on ideas that participants brought to the meeting. The teams that developed projects and proposals based on those ideas understood how the cognitive frames from the different team members complemented each other and could be utilized effectively toward a successful proposal. For example, a successful proposal from the Geoscience Ideas Lab brought together participants with cognitive frames that included educational research, faculty professional development, and experience with minority-serving institutions (MSIs) and community colleges; and a successful proposal from the Biology Ideas Lab included cognitive frames in educational research in science education and practical in-the-classroom biology teaching experience.

CHARACTERISTICS OF SUCCESSFULLY FUNDED PROPOSALS

About one year after the meetings we searched the National Science Foundation's Award Search website to find participants listed as principal investigators on proposals that had received funding since the end of the Ideas Lab meetings. We found a couple of awards for projects similar to those presented on the last day of the Ideas Lab meetings and whose principal investigators were members of the team that made the presentation. We selected those awards and looked back through our notes and survey data to identify any information that would help us understand where the ideas for those proposals came from, how the team members worked together to develop the idea, how team members overcame disciplinary barriers, and what characteristics had made these projects successful. To summarize our findings, we found that proposals that were successfully funded came from smaller teams that consisted of three to five members, and team members were able to articulate how team members' cognitive frames contributed to their proposal.

We used the Geo Opportunities for Leadership in Diversity (GOLD) Ideas Lab meeting, which we hosted two years after the pilot Ideas Lab meetings, to test whether we could identify teams that produced successfully funded proposals based on our findings from the pilot Ideas Lab meetings. We posed a series of questions to meeting participants in a post-meeting survey about groups that presented on the last day to see if we could correctly predict which teams from the meeting would receive funding.

Based on participants' responses about team size and ability to articulate the contribution of team members' cognitive frames to the proposals, we identified two teams we predicted would receive funding as well as five teams that would not receive funding. Same as we did for the pilot Ideas Lab meetings, we searched the National Science Foundation Award Search website nine months after the meeting and found participants who received funding since the Geo-Gold Ideas Lab meeting. Based on our predictions, we correctly identified the two teams that received funding and the five teams that did not. The successful teams were comprised of three to five members, and members were able to articulate the contribution of team members' cognitive frames to the proposals.

THINKING OUTSIDE THE BOX, BUT NOT TOO FAR OUTSIDE THE BOX

While the goal of Ideas Lab meetings is to facilitate the creation of big ideas and innovative proposals to address the meeting topic, innovation requires thinking outside the box, but not too far outside the box. While the cognitive frame could be seen as limiting innova-

tion, it provided a useful scaffold on which to build a proposal. With assistance from the meeting mentors and input from other meeting participants, the proposals went beyond what had been done previously. The two proposals that we identified as coming out of pilot Ideas Lab meetings both leveraged participants' prior knowledge in new and novel ways.

How receptive proposal reviewers were to new ideas was open to debate. One Ideas Lab meeting participant who contributed to the member check by reviewing and commenting on a draft of our findings observed that the goals of the Ideas Labs meetings appeared to be at odds with the way proposals were reviewed for funding. Proposals were selected because they conformed to the kinds of proposals that had been funded previously and were more closely tied to conventional ideas than the unfunded proposals. To quote:

"Many attendees assumed that panels evaluating proposals that originated in Ideas Labs would include people familiar with the transformative nature of the Ideas Labs' goals. In reading proposal reviews, we and others found this not to be the case--reviewers in general were very skeptical concerning the "third-third" aspects of the proposed projects. Given that, it is not surprising that successful proposals were those most closely tied to conventional ideas. This was an area of frustration among participants with whom I spoke. They felt they had been led to believe that NSF was looking for innovative, transformative proposals, but when they produced such proposals they were declined by panels operating under the usual assumptions and constraints."

The participant raises a valid point. Since the proposals that originated in the Ideas Lab meetings were reviewed through existing NSF funding opportunities, members of the review panels may not have been familiar with the transformative goals of Ideas Lab meetings. Therefore, proposals that were more closely tied to conventional ideas would be more likely to receive funding than proposals that might be described as more ambitiously third-third and based on original ideas. Following this logic, if NSF is committed to funding more ambitious "outside the box" proposals, one way this could be accomplished is by following the Sand Pit meeting methodology, in which funding decisions are made at the end of the meeting by organizers/funders in attendance. These organizers/funders would be familiar with the transformative goals of Ideas Labs, and therefore would be more willing to fund projects deemed too "outside of the box" by traditional review panels.

From our analysis of the data, however, we believe there is more to why projects were funded than the vehicle by which they are reviewed. We found that all participants came to the meeting with cognitive frames, and that meeting participants contributed these cognitive frames to their teams' proposals. But it was the teams that could articulate how team members' cognitive frames contributed to their team's proposal that were awarded funding. We suspect that teams that received funding made a better case as to how their team members' expertise contributed to their proposed projects and did not try to go far beyond their areas of expertise. Perhaps non-funded proposals, while being "third-third," went too far beyond what team members had done previously and were considered by panels to be too risky for funding, or the scope of the proposed projects was so large they seemed unmanageable. We are not able to answer through this research whether the funding mechanism for Ideas Lab meetings affects the kind of proposals that receive funding, or the reasons why some proposals were not funded, but we do find it a topic worthy of additional research.

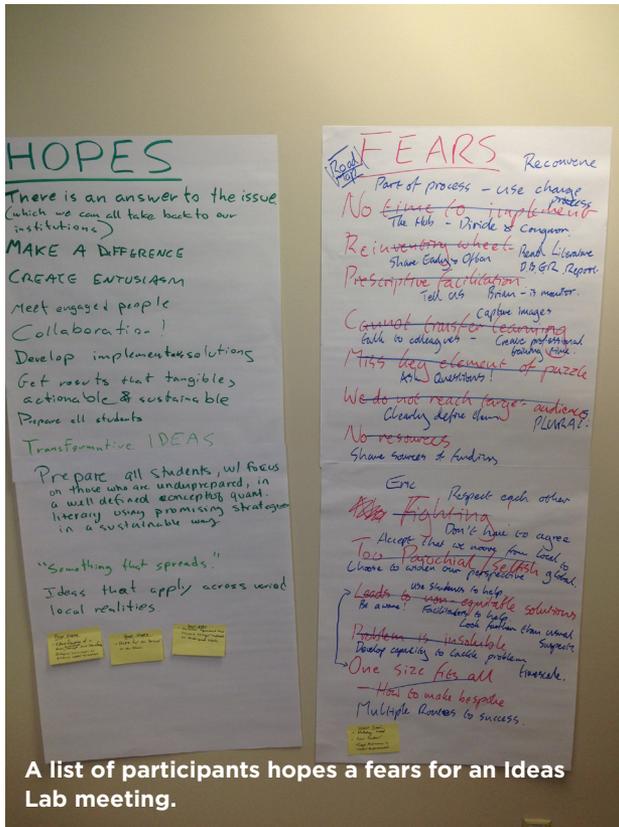
TEAM SIZE

Team size mattered in the creation of project ideas that turned into funded proposals. Smaller groups had less disagreement and an easier time developing consensus among team members and distributing work related to the development of a project idea (i.e., it is easier to have four people agree on something versus ten people). Smaller group composition allowed team members to grasp both the big picture and the details of the project.

In a larger group, with many team members trying to contribute their respective cognitive frames, proposals combined multiple cognitive frames and seemed to constitute several different projects rather than one. In larger groups, one or two people sometimes drove the project idea, with others helping out. Ultimately, these proposals did not develop into funded projects after the meeting. We should note that team size does not guarantee success. While some of the groups of three to five people developed innovative projects that became funded



"Picasso" portrait drawings hanging on a wall. The outcome of a get-to-know-one-another activity.



A list of participants hopes a fears for an Ideas Lab meeting.

proposals, smaller teams also presented some of the weakest project ideas. Once again, we attribute weaker teams to personal characteristics of team members. They either did not have the qualities of someone with a propensity for interdisciplinary research or their cognitive frames did not complement each other.

MEETING PROCESS - DEVELOPMENT OF IDEAS INTO PROPOSALS

The following provides a day-by-day description of activities at the pilot Ideas Lab meetings based on meeting notes and survey data, and goes into more detail than the description of the meeting methods provided in the literature review. While the exact process followed for each Ideas Lab meeting is unique, most meetings follow the same general format. The stages described below are associated with days, but not all activities align with the same day.

Day 1 - Awareness and discovery

When participants know that people from other disciplines or sub-disciplines will be at the Ideas Lab workshop, it affects the way they interact with others and

encourages them to ask questions that raise their multidisciplinary awareness. However, it takes a bit of time to bond before participants start talking. Day One of Ideas Lab was intended to facilitate participants' getting to know each other and discovering the expertise in the room. The day included several different activities to mix and "crash-introduce" participants, to get to know who is there and why, and to spark some interest on ideas and cooperation. One example was an activity called "knowledge mapping," which mapped the expertise of members in the group. It helped participants meet others from different domains, ask questions, share ideas, and identify where their interests overlapped.

Another brief activity on Day One was for participants to write their hopes and fears for the five days of the meeting and share and discuss them. Probably the most engaging get-to-know-one-another activity on day was the "Picasso" portrait drawing and speed-dating activity. While sitting in pairs and facing each other, participants were asked to put their notepads inside a paper bag and draw a portrait of the person in front of them without looking at the drawing. Then each participant carried their Picasso portrait with them to a "speed dating" rotation, where they got to talk about themselves and hear about others. After that, everybody hung their portraits, together with statements about themselves, on a board. The Picasso activity was a big ice breaker that brought laughter and energy to the room, but also allowed participants to get to know each other.



Participant questions generated from Ideas Lab activities take up an entire wall.

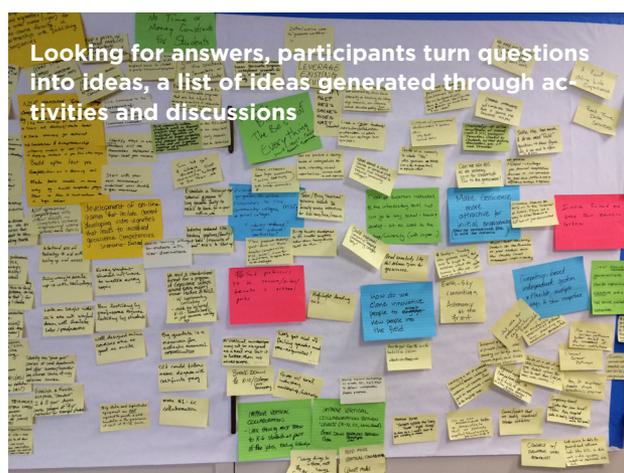
Participants wore improvised name tags made of sticky notes that had first names only. Informal name tags helped to achieve two goals: facilitate introductions and level the field. Lack of information about titles, background, and affiliation invites questions and discovery as the meeting unfolds.

The goal for Day One was for everybody to know who else was in the room, to feel comfortable talking to everyone else, and have a general idea of who the others were and why they were there. That goal was accomplished by Monday night at all three Ideas Lab meetings.

Day 2 - Defining problems

The Day Two goal was to present the overall landscape of the meeting topic, frame questions, and define the problems that needed to be solved. Interaction, discussion, and stakeholders' input broadened understanding of the topic and let participants identify common areas of interest. Many ideas were generated from which participants chose the most promising.

Facilitators asked participants to align themselves around problems they found intriguing. This exercise encouraged people to explore, ask questions, and find common ground. In the Biology Ideas Lab, for instance, a chemist was surprised to find out how many problems were similar between chemistry and biology and how much the two disciplines had been silo-ed. Participants were grouped around tables to generate questions and identify problems requiring solutions. They posted questions on a "Question Wall" in a breakout room and reflected on questions generated by others. Groups then began narrowing down questions to focus on one problem they would tackle. Next, everyone re-assembled in the main plenary room, where each group took on another group's questions and wrote a problem statement that would apply.



Looking for answers, participants turn questions into ideas, a list of ideas generated through activities and discussions

The intent of developing problem statements was to get participants to attach themselves to an idea, find others they could work with, and then leave that group and start over. At the end of day two, the group had a long list of open-ended questions. (The engineering Ideas Lab was the most inquisitive, generating around a thousand ques-

tions.) Mentors and facilitators organized those questions, providing input on which they thought were the most useful to address. The purpose was to identify questions that address the most important problems contained in the meeting topic. Development of problem statements also got participants to start the process of self selecting and identifying with and exploring particular problems.

Day 3 - Ideation

The activities during the first two days of Ideas Labs set the stage for Day Three, which was organized to generate ideas and form teams around them. This was when participants were encouraged to begin coming up with third-third ideas, those that would break new ground and reach beyond existing boundaries.

The facilitators laid out some ground rules for generating innovative ideas:

1. Go for quantity when generating ideas.
2. Defer judgement – don't judge your own ideas or those of others.
3. Go wild and nuts.
4. Combine and build on others' ideas.

Day three started with a silent activity for all participants to walk to the Question Wall from the previous night, read through all the questions, reflect, and write comments and thoughts on post-it notes with enough context to be able to convey the idea to others. Then,



Ideas posted on Evaluation Boards are reviewed by a participant

grouped around tables, they shared and discussed their ideas while mentors listened. The objective was for each group to formulate and unite behind ideas that could be presented to the larger group. Their post-it notes, together with new ideas, went on two new blank white boards ("Ideas Wall") as a fresh start of ideas for day three [3 photos]. At that point, the group had two double boards as a starting point for ideation - the Question/Problems Wall and the Ideas Wall.

Creation of the Ideas Wall was followed by another speed-dating activity, in which pairs of participants discuss ideas from the Wall and made notes on post-its, which were added to the Wall. Participants switched partners every five minutes to share more ideas. The point of this exercise was simply to explore. However, this was the point at which people started to group around ideas and initial teams of three to four members began to form. Some of those teams were also interdisciplinary. One team from the geoscience Ideas Lab for instance, joined people with backgrounds in formal education, workforce, hands-on learning, and the military.

Next, facilitators engaged participants in a creative thinking exercise intended to stimulate third-third ideas. Participants were asked to list things that human beings cannot do but that it would be very cool if they could. This generated a lot of participation, ideas, and laughter - people were very creative and came up with around three dozen suggestions. Most common,

however, were "second-third" ideas offered by many participants. After the creative exercise, the groups reconvened and tried to come up with radical third-third ideas. Each table had to generate one big idea to share with the group. Participants were encouraged to post every single idea they came up with on post it notes, big posters on the windows and the Idea Wall. At all three Ideas Lab meetings, about 100 ideas on post-it and bigger notes filled up the space. Participants were given time to examine the ideas and reflect on them.

From this point on, the process proceeded in multiple iterations. Participants split into breakout groups to further refine ideas and come up with one to present to the whole group for feedback. Then each team went to a breakout room for further refinement. This cycle, repeated multiple times in the last three days of Ideas Lab, formed the main engine behind the process of idea generation and proposal development. The point of this dynamic process was to prevent teams from reaching premature conclusions and to develop a mature understanding. After each presentation, participants took some time to rank ideas across different criteria on the X and Y axis of the Evaluation Board and to leave feedback about the idea on post-it notes. By populating the board, participants were evaluating, merging, modifying, and evolving ideas. If an idea didn't meet the evaluation criteria (or scored poorly on some criteria), participants could modify and enhance it before presented again to the group.



For each round of reiteration and refinement, participants were reminded to consider the following points:

- Brief recap of what the idea is about.
- How it is innovative.
- How to incorporate Pluses, Potentials, and Concerns (PPC) feedback.
- What are the project's milestones?
- How to recognize success.
- Who is in the team and what are their contributions?
- What additional resources/expertise/facilities does the group need – cry for help?.

By the end of day three, for the most part, participants had self-selected into teams, become excited about some ideas, and were starting to come up with where they might want to put their energy. They were also receiving feedback from peers and mentors. In the case of the Biology Ideas Lab, however, mentors concluded at the end of day three that no truly groundbreaking ideas had been offered; participants and teams were gravitating around first-third and second-third ideas or reiterating questions and problems. Participants preferred to remain within their comfort zones rather than take risks and push boundaries. Some ideas strayed from the subject of the Biology Ideas Lab. Nonetheless, mentors felt Day Three had been a huge progress overall: An affinity had formed among participants; en-

ergy remained high through a long and fatiguing day; and the rather chaotic thinking of the first two days had been streamlined and channeled into generating ideas.

The role and weight of mentors evolved throughout the meeting. On the first and second day, they played a passive role. From the third day on, as teams coalesced and proposal development became the focus, the mentors assumed a leading and a crucially important role. That is when their insights and expertise were needed in providing direction to teams and proposals, and when the focus for participants shifted from the facilitators to mentors.

NSF's goal in sponsoring the Ideas Labs was to have participants address important problems and take a personal interest in generating creative solutions. Agency staff were confident that ultimately, the accumulation of a critical mass of teamwork and ideas would lead to the development of proposals. For them, however, the key objective of the lab was big ideas – ones that could grow into transformative proposals even months down the line. In what proved to be a pivotal moment, an NSF official outlined what funding opportunities were available for proposals that might emerge from the Ideas Lab meeting. The announcement changed the tenor of the meeting from a quest for ground-breaking ideas to practical proposal development.



Day 4 - Proposal development

Day four marked the point during the meeting when ideation began to blend into proposal development, and when ideas began to gain structure as proposal outlines. The process of multiple iterations of developing ideas on paper, discussing, presenting to the group, getting feedback from peers and mentors, and refining them continued. However, the prospect of funding opportunities, announced the day before, brought a noticeable change in the teams' approach. There seemed to be a moment in all the Ideas Lab meetings when attendees shrank from brainstorming big, bold new ideas and became very practical about developing proposals. Teams started to shape proposals in the \$500,000 to \$2.5 million range and addressed such things as implementation plans; timelines; degree of novelty; measurement, evaluation, and assessment; stakeholder identification; partnership; buy-in; funding; and sustainability. NSF provided some clear guidelines about proposals and what they should include:

- Working title
- Summary of the idea and the problem it addresses
- Enhancement and developments since last presentation
- How does it improve undergraduate education?
- How has it maximized the novelty?
- Which commitments – from organizations, entities, individuals, or resources – can the team leverage to implement this idea (beyond a letter of support)?
- What power structures will resist change and how will the team address this?

Day Four also included mentor clinics, in which mentors sat with individual teams and critically examined their proposal ideas. These clinics served to enhance and refine ideas and propel them forward before the final presentation on the last day of Ideas Lab. Teams and mentors covered a lot of ground. However, participants noticed that constructing a proposal and finding cohesiveness in larger teams (more than 3-4 people) was a challenge, because individual ideas and agendas intruded on discussions.

Day 5 - Final presentations

On the last day of Ideas Lab, teams had eight minutes each to present their final proposals to the group.

In the post-meeting survey, a majority of participants reported that the proposals blended multiple disciplines and specializations. Team proposals featured, for instance, engineering, chemistry, science, social science, psychology, sociology, education, academia, ecology, making and craftsmanship, and art. They also

tapped various team members' expertise in terms of content, methods, grant writing, and commitment to underserved groups and social equality. One proposal from the geoscience Ideas Lab blended Native American culture, earth and space science, field geology, oceanography, life science, curriculum development, access by disabled persons, and community outreach. A second proposal from the geoscience Ideas Lab mixed a hard rock petrologist with a sedimentology/geomorphology/environmental scientist and a meteorologist. Teams from the Biology Ideas Lab brought perspectives from multiple biology specializations, including botany, biochemistry, ecology, ecological physiology, and histology. Going beyond biology, some proposals spanned disciplines such as math, computer science, undergraduate instruction, educational measurement, social science, and program evaluation, as well as academia, administration, business, and art. In addition to disciplinary background, team members also brought a diverse range of skills that were reflected in their respective proposals.

EXAMPLES OF FUNDED PROPOSALS FROM PILOT IDEAS LAB MEETINGS

About one year after the meetings we searched the National Science Foundation's Award Search website to find participants listed as principal investigators on proposals that had received funding since the end of the Ideas Lab meetings. We found a couple of awards for projects similar to those presented on the last day of the Ideas Lab meetings and whose principal investigators were members of the team that made the presentation. We selected those awards and looked back through our notes and survey data to identify any information that would help us understand where the ideas for those proposals came from, how the team members worked together to develop the idea, how team members overcame disciplinary barriers, and what characteristics had made these projects successful. To summarize our findings, we found that proposals that were successfully funded came from smaller teams that consisted of three to five members, and team members were able to articulate how team members' cognitive frames contributed to their proposal.

In the following descriptions of the two funded proposals that came out of the pilot Ideas Lab meetings, we have removed identifying information about the principal investigators and projects.

Funded Proposal from NSF Ideas Lab: Biology

The biology Ideas Lab meeting was to integrate quantitative literacy into a biology core curriculum and to study its effectiveness and/or impact to generate knowledge that will inform broader implementation. Through a principal investigator (PI) search we identified one funded project whose PI and co-PIs matched a team that presented on the last day of the Biology Ideas Lab meeting. All the PIs were from large public universities in the Midwest. They included an evolutionary biologist and higher education researcher, a biologist/community ecologist, and an ecologist.

Synopsis of project

The project addresses the growing need to better prepare undergraduate biologists with quantitative and computational skills needed to be successful in the workplace or in graduate school. The full integration of mathematical reasoning skills into undergraduate biology classrooms has been challenging, in part because of the rapid pace of change in many biological disciplines and an academic reward system that often overlooks pedagogical development and research.

The project builds on the investments of existing communities by coordinating the efforts and resources of diverse groups that are already involved in quantitative biology education reform. This approach allows the project to amplify the strengths of organizations like professional societies and specialized curriculum projects while streamlining the communications and coordination required to expand the broader community of reform-minded faculty educators in quantitative biology (QB).

Proposal development process during Ideas Lab

In the post-workshop research survey, one of the project's principal investigators shared some insights about the process of proposal development from Wednesday through Friday of the Ideas Lab meeting. Table 2 summarizes the PI's description.

Table 2. Factors found to impact interdisciplinary scientific research

Wednesday	Thursday (when the bulk of the work was done)	Friday
Just a barebones idea - using a distributed course model.	More scaling up, thinking about incentives for participants - these changes stemmed from group input and feedback from the larger group.	The mentors' guidance Thursday evening spawned lots of brainstorming and reformulating our ideas to make the work of greater, broader appeal.

Factors that contributed to a successful proposal

The project team members had expertise in science education as a research focus, and were applied, in-the-classroom, experienced disciplinary researchers who, as a professional goal, were trying to teach better. They also crossed many of the disciplinary boundaries in biology. Because of the valuable input from the larger Ideas Lab group of participants, additional layers of perspective were integrated. One of the PIs described coming into Ideas Lab with several ideas and preconceived notions that he quickly realized were “too small” for the grand challenge presented to the team. However, he also brought knowledge and professional experience in a particular kind of course, which generated the seed of an idea that became a group project. The Ideas Lab experience and his peers helped him see the potential of using an existing model in a different way.

Barriers to proposal development

Based on interview transcripts, meeting notes, and survey responses from team members, we did not identify any obvious barriers to the development of the proposal.

Funded Proposal from NSF Ideas Lab: Geoscience

A major goal of the Geoscience Ideas Lab meeting was for participants to develop a set of interdisciplinary proposals that present novel approaches to undergraduate geoscience education; develop essential competencies and skills for the workforce; and increase access for diverse student populations. In the year after the meeting, we were able to match one set of funded geoscience proposals with members of a team from the Geo-Science Ideas Lab meeting who received a cooperative award.

Team background

The team worked at large public universities located throughout the West, Midwest and eastern United States. The team members reported having geoscience backgrounds, but also backgrounds in education, educational research, faculty professional development, and experience with minority-serving institutions (MSIs) and community colleges. While having a background in geoscience was important to the development of the proposal, the team members also contributed their knowledge of education, education, research, faculty professional development, and experience with minority-serving institutions and community colleges to the proposal.

Synopsis of project

This project identifies strategies that will help two-year technical and community colleges and minority-serving institutions better prepare underrepresented students for geoscience careers. Many underrepresented minorities attend two-year technical and community colleges or minority-serving institutions as undergraduates; but these

institutions commonly lack adequate geoscience programs. This project brings together partner institutions, individual faculty, educational resource providers, educational researchers, and geoscience employers in a series of focused workshops to determine the systems that would be ideal for increasing geoscience capacity at the targeted institutions. It focuses activities at the institution and system level, directly involving 20 community colleges and minority-serving institutional partners and faculty and 30 additional stakeholders.

Proposal characteristics

We have additional details about this proposal because on the last day of the Ideas Labs meeting, teams were supposed to highlight what made their proposal strong why it represented a third-third idea. The team treated education as a system and had milestones set for three years ahead with a vision for sustainability and scalability. The proposal focused on making better use of existing course and curriculum resources through expert facilitated faculty development, making those resources more widely available, and creating a community of practice that sustains the reforms. The team specifically highlighted the following features that made their proposal strong:

- Intellectual merit – builds upon what exists already by making better use of existing course and curriculum resources.
- Customizable – plug and play content;
- One-stop shop with support;
- Supports community.
- **Novelty:** goes beyond just a connection; builds an Amazon.com-style warehouse.
- **Feedback:** will not just build it and hope that partnerships come. There will be a person to target and market the idea to two-year colleges and an existing mechanism for feedback and suggestions of who will be targeted. There will also be guest editors.
- **Sustainability and Scalability:** there will be quality assurance and Amazon-style customer reviews; outreach; 3- to 5-year pilot to build structure and prototype.
 - 3-year pilot builds system and prototypes
 - Copyright
 - Number of courses developed through two years of workshops (n>30)
 - Service for fee beyond this period for development of new courses
 - Solicit in-kind and monetary support from targeted industries for their specific needs
- **Measurement of Success:** evaluation and assessment embedded; back up user analysis; multiple

scales; tracking alumni; use social network analysis.

- **Milestones:** two to three-year conceptualizing phase.
 - Year 1 = at least five two-year colleges and Minority Serving Institutional faculty served, five courses developed
 - Year 2 = 30-40 individual faculty, 30 courses developed
 - Year 3 = five to ten groups (departments and/or consortia), five curricula and ten new courses developed
 - Increased connectivity of Community
- **Team members and Stakeholders:** Principal Investigator and management group; advisory board; mixture of full-time and post-docs; members of two-year colleges and Minority Service Institutions and industry; marketing person; foundry consultants; tech/web support; internal and external evaluation and assessment.

The team also explicitly highlighted the features that qualify their proposal for the third-third category:

- Addresses education as a system.
- Includes people, resources, and information.
- Supports transition from intuitive to informed design.
- Involves a needs assessment –partnerships to define needs.
- Incorporation of Discipline-Based Education Research (DBER).
- Transition of evidence-based teaching and learning into practice.

Proposal development process

In the post-workshop research survey, two of the project’s principal investigators shared some insights about the process of proposal development from Wednesday through Friday, the days when the majority of the proposal work took place. Table 3 on the next page illustrates the results.

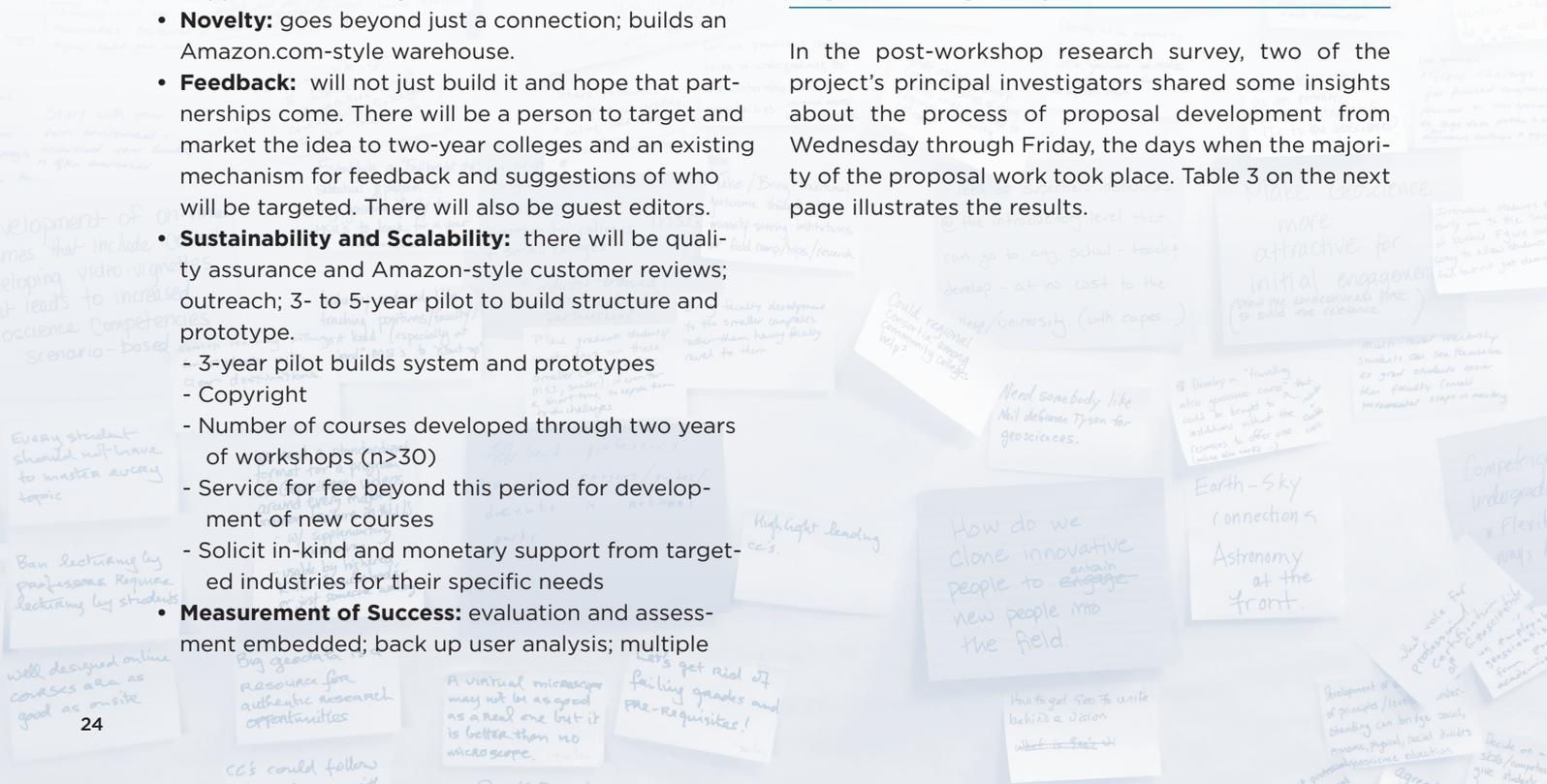


Table 3. Factors found to impact interdisciplinary scientific research

Wednesday	Thursday (when the bulk of the work was done)	Friday
<ul style="list-style-type: none"> • Ideas brainstorming and crystallization, defining a problem. • Identified team members • Created a diagram of project components • Prepared first draft of project presentation to group 	<ul style="list-style-type: none"> • Incorporated suggestions from the group into the proposal draft • Created a set of notes in NSF proposal language to organize ideas • Refined key outcomes and products • Worked on proposal presentation second draft • Dove into logistics, roles, implementation, and sustainability • Presented ideas to mentors and received feedback • Went to the bar as a team and played darts 	<ul style="list-style-type: none"> • Refined project diagram for final presentation • Prepared a draft proposal outline with all previous presentations and notes • Prepared and delivered final team proposal to the group • Created a one-page project summary

According to project members, the process of idea generation and proposal development stemmed from their own experience and awareness of current efforts in undergraduate STEM education reform, and not specifically from ideas raised at the meeting, which had more of a role in refining their proposal.

Factors that contributed to a successful proposal

In the view of team members, the following Ideas Lab features contributed to the creation of a successful proposal:

- The immersive environment and the ease of mixing, mingling, and connecting with everyone at the meeting.
- Specialization (discipline) rarely came up in conversations, unless it was to clarify jargon.
- Everyone seemed to be familiar with some aspect of science education and had somewhat of a science background, and nobody was a pure researcher.
- Having a wide representation from two-year colleges, four-year colleges, and universities was crucial. Team members came from different types of colleges with different institutional structures, and that really helped them flesh out an idea that would work for anyone.

Barriers attributed to academic discipline or specialization

In the view of the team members, the meeting produced a divide between informal and formal science education. This divide affected team composition, because team members decided themselves to form two groups and chose to join either an informal science education group and a formal science education group. The meeting had excellent representation from both college/university faculty and informal education and outreach providers. However, the goals of the two groups could run counter to one another, which became evident later in the meeting during self-selection into project teams. The formal educators focused on either creating products (courses, curricula) or services (faculty professional development) aimed at undergraduate institutions; the informal educators tended to focus their projects on settings outside of universities. Both types of projects were needed to confront the workforce challenge in the geosciences, but ultimately there was little true collaboration between the groups.

SUMMARY AND CONCLUSIONS

Organizations that fund interdisciplinary research and collaboration play an important role promoting and advancing interdisciplinary agendas, yet little research or theory has focused on how funding organizations can promote the creation of novel interdisciplinary proposals by hosting meetings. Our research on three pilot Ideas Lab meetings in 2014 and a subsequent meeting in 2016 aims to help fill that gap. We found that barriers to interdisciplinary collaboration were mitigated largely through the participant selection process, which favored participants with a propensity for interdisciplinary collaboration, and through activities built into the Ideas Lab meeting process. An example of such activities was the “Jargon Wall,” a space where participants could post and explain discipline-specific vocabulary and acronyms. AEIR researchers found that funded proposals that emerged from an Ideas Lab meeting came from smaller teams consisting of three to five members, who could articulate how team members’ cognitive frames contributed to their proposal. We refer to prior knowledge as a cognitive frame, which can include disciplinary thinking, knowledge gained through professional activities, or knowledge gained through personal activities. Additionally, the system-level focus of the meeting topics lessened the centrality of discipline and increased the importance of knowledge gained through professional and personal activities.

FURTHER CONSIDERATIONS

Observation of Ideas Lab meetings pushed our thinking on what funding organizations should consider when planning interdisciplinary meetings and workshops. Discussion within funding organizations about the goals of innovation is a useful exercise. Two questions come to mind: What is the nature of useful innovation? When proposals are supposed to effect system change, who within the system should be invited?

WHAT IS THE NATURE OF USEFUL INNOVATION?

On one hand, innovation is often thought of as big and bold, game changing, high risk, and high reward. Some meeting participants expected that such an outcome would be NSF’s goal for the Ideas Lab meetings. However, the Ideas Lab innovations that ultimately secured funding were relatively small and incremental. We would characterize the funded projects as a portfolio of small innovations that, in sum, can eventually lead to changes in the matters addressed by the meetings. Two factors that we believe influenced proposals that proved successful were, one, the timing of when the prospect of funding was broached (midway through the meetings) and, two, an understanding within teams of

how their team members’ cognitive frames contributed to their proposals. Some meeting participants believed proposals reviewed by traditional NSF review panels after the meeting excluded proposals that were more ambitious – “third-third.” We believe the proposals that were funded could be considered “third-third” proposals. Nonetheless, they raised a question: If a funding organization is intent on seeking out bigger, riskier proposals, how might the meeting be structured to ensure such a result? We believe that if funding organizations made the goal of “bigger” and “riskier” projects clear to participants at the beginning of the meeting and then awarded funding at the end, riskier and more ambitious proposals would emerge.

WHEN PROPOSALS ARE SUPPOSED TO EFFECT SYSTEM CHANGE, WHO WITHIN THE SYSTEM SHOULD BE INVITED?

The Ideas Lab meetings we observed addressed system-level changes rather than technical research problems. The system-level focus decreased the emphasis on disciplinary differences while increasing the importance of other areas of participants’ cognitive frames, like a participant’s professional and personal experience related to the meeting topic. Including people who occupy various places in a system will ensure that varied and appropriate cognitive frames are represented and contribute to novel third-third proposals. For example, inviting people who may not traditionally contribute to NSF proposals, like a college president, human resource staff from a private company, staff from a media organization, or non-academic university staff, could expand the range of cognitive frames represented and help produce new and novel ideas. The goal of innovation, in this case, is the integration of novel cognitive frames that lead to innovative proposals, not solely the generation of novel ideas.

EMERGING QUESTIONS FOR FUTURE RESEARCH

Our observation of Ideas Lab meetings has identified a couple of questions for future research. One is whether the funding mechanism used to make awards following Ideas Lab meetings affects the kind of proposals that are funded. In the meetings we studied, proposals that emerged from Ideas Lab meetings were directed to existing NSF funding opportunities and were reviewed by traditional review panels. These panels may not have appreciated, nor even been aware of, the Ideas Lab goal of creating third-third proposals. If, instead, funding followed the Sandpit model, in which organizers/funders are present during the meeting and make awards at the end, would bolder, riskier, third-third proposals be more likely to receive funding?

Another question for future research is what enduring impact the Ideas Lab experience has on participants. Participants reported to us that the Ideas Lab meetings had a lasting influence on them and their careers. A useful study would consist of interviews with meeting participants one to three years after the meetings to learn about the impact of Ideas Lab on: expanded networks; interdisciplinary collaborations; bridges across disciplines, proposal development; publications; work practices at their home institutions; and career pivots. Such a study would help us begin to understand potential impacts of Ideas Lab meetings beyond funded proposals.

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Questions or comments?

Contact Brian L. Yoder

Director of Assessment, Evaluation and Institutional Research

American Society for Engineering Education

b.yoder@asee.org 202-331-3535



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