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Charting the Intersection of Informal STEM Education and Science Communication:

Results of a Social Network Study

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Abstract

The professional fields of informal science education (ISE) and science communication (SciComm) have developed in parallel, despite considerable overlap in goals and methods; both aim at learners of all ages and both provide opportunities to encounter science outside of formal school or university settings, and they often intend to support broader science literacy. There are many differences between ISE and SciComm, including their histories, their support structures, key actors, and the research literature that undergirds the two fields. Nonetheless, both fields seem to grow closer and are both the target of a major funding program by the U.S.-based National Science Foundation (NSF) Advancing Informal STEM Education (AISL) program. The AISL program is supported by the NSF-funded Center for the Advancement of Informal Science Education (CAISE).

In order to both inform the efforts of CAISE to connect individuals and cross-pollinate ideas in both fields, as well as to track progress CAISE may make in achieving these goals, CAISE conducted a bibliometric and a social network study to establish a baseline state of connectivity between ISE and SciComm. The social network study asked 657 mostly senior practitioners and researchers in both fields to complete a questionnaire that aimed at answering the questions, "Which individuals are influential on individuals who identify as either ISE or SciComm?" and "What professional resources (studies, reports, professional tools, and websites) do individuals who identify as either ISE or SciComm rely on for their work?"

Results of the study suggest that the communities of ISE and SciComm are still quite distinct. Few professionals in one community named professionals or resources from the other community as influential on their work. This finding is corroborated by the bibliometric analysis which found distinct and different patterns in the content of academic publications between ISE and SciComm. Furthermore, practitioners in general have less visibility in both fields: practitioners and researchers were more likely to name researchers as influential to their work than they were to name practitioners.

Resource use in both fields showed some distinct and some common patterns. For instance, researchers in SciComm named fewer individuals in the area of broadening participation in STEM than did ISE researchers, ISE practitioners, or SciComm practitioners. On the other hand, custom-made assessments are far more commonly used than published ones in both fields, suggesting that much research and evaluation relies on ad hoc approaches in order to align measures to project-specific goals or outcomes. And practitioners in both fields rely heavily on research syntheses and similar forms of digested information rather than on primary research and evaluation literature.

Introduction

Since 2008, the Center for Advancement of Informal Science Education (CAISE) has supported professional learning and connectivity among the communities that comprise principal investigators (PIs), co-principal investigators (co-PIs), researchers, evaluators, and senior staff working on projects funded by the National Science Foundation's (NSF) Advancing Informal STEM Learning (AISL) program. CAISE audiences also include professionals who are potential NSF AISL PIs and co-PIs, and their stakeholders and funders. The broader goal of CAISE, therefore, is to strengthen the field of informal science education (ISE) through connecting, characterizing, and communicating the work of individuals and projects in the AISL community.

In late 2016, CAISE received its third multi-year award to be a resource center for the AISL community. As part of its new scope, CAISE was charged with extending its reach from individuals who see themselves primarily as part of ISE to those who identify primarily as part of the science communication (SciComm) community. The rationale for this new effort was three-fold.

Firstly, while there are some differences between the goals of SciComm and ISE (see below), there are also considerable overlaps, and both fields seek to reach the same audiences in settings outside of formal education. In fact, a subset of AISL grantees already consider themselves to be equally or more aligned with SciComm than with ISE (for example journalists and documentarians, science festival organizers, or organizers of dialogue-type events between scientists and the interested public).

Secondly, two-way science communication, often referred to as science engagement (Storksdieck et al., 2016) is becoming more popular, and is making SciComm more similar to ISE.

Thirdly, while there is a similar knowledge and evidence base that both fields can draw upon, ISE researchers or practitioners are currently not likely to acknowledge the emerging research in SciComm, nor, conversely, do SciComm practitioners and researchers reference ISE literature.

Extending the reach of CAISE from ISE into SciComm requires a more fine-grained understanding of the current state of overlap between ISE and SciComm.

ISE and SciComm as amorphous fields with considerable overlap

The fact that the former NSF ISE program (now called the NSF AISL program) funded activities that are both ISE (e.g., afterschool science programs, and museum exhibits and programs) and SciComm (e.g., science documentaries, science radio shows, and the featuring of science on the news) is an indicator of the overlap between the two fields, just as much as it is an indicator of the fluid boundaries and fuzzy definitions that make a clear distinction between ISE and SciComm next to impossible. Yet, there exist strong differences in core values and goals within institutions that clearly fall within ISE and SciComm.

Within the field of ISE, there are strong differences between museum exhibit designers and museum youth program leaders, with the former often more concerned with concepts or phenomena of science and the latter equally if not more concerned with conveying the processes of science while supporting broader youth development goals.

Within the field of SciComm, there are strong differences between science festival leaders or presenters who engage in hands-on activities for families and youth and those who work as science radio or television producers who create complete packaged narratives, often aimed at an adult
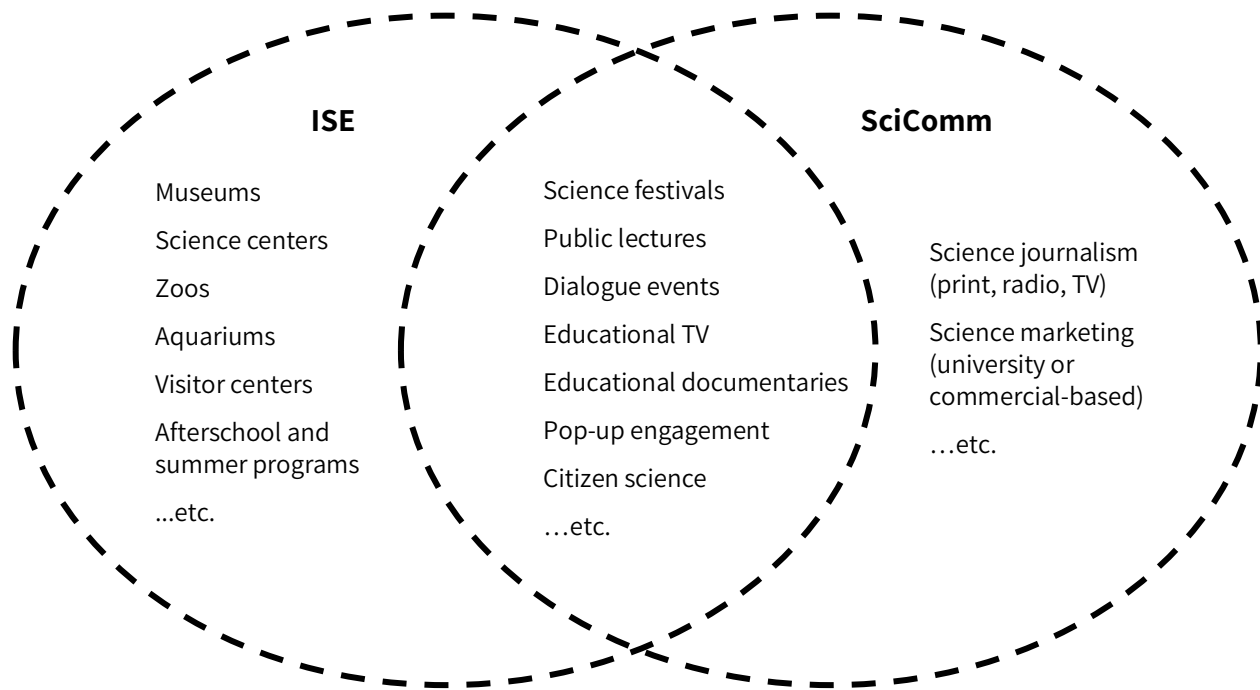
ISE

Museums

Science centers

Zoos

Aquariums

Visitor centers

Afterschool and summer programs

…etc.

Science festivals

Public lectures

Dialogue events

Educational TV

Educational documentaries

Pop-up engagement

Citizen science

…etc.

SciComm

Science journalism (print, radio, TV)

Science marketing (university or commercial-based)

…etc.

Figure 1. Tentative conjecture about activities in the fields of ISE and SciComm and places of overlap (where program leaders might identify with either or both fields).

audience in support of public understanding and enjoyment of current science (see Figure 1). Science journalists, for example, embrace a professional ethic around neutral reporting of facts to an interested public. They do not see themselves as promoting appreciation for science, or recruiting more youth into science careers.

On the other hand, many science communicators who are not journalists and who represent science-based organizations such as universities or research institutions may see their main role as advocating for science with the public and with policy-makers

Professionals within ISE or SciComm likely identify with their setting of employment

A CAISE-funded landscape study of the ISE field by Falk and colleagues (2010) found little cohesion and joint identity among AISL (then called ISE)

PIs. Individuals identified with their settings rather than the field. For instance, they saw themselves as museum educators, youth program leaders, or science documentary makers. This lack of an overarching or primary ISE identity is further enhanced by the fact that there currently is no single ISE journal, but rather a number of different journals and magazines (youth development, science education research, museum studies, visitor studies) to which different actors from within ISE contribute or subscribe. Nonetheless, various academic syntheses studies of ISE, in particular those by the US National Research Council that were funded by the NSF AISL program (Fenichel & Schweingruber, 2012; NRC, 2009 and 2015) have identified common practices and provided conceptual or theoretical frameworks for how various efforts tie into a larger whole within ISE.

These reports provide a partial foundation for defining a field of ISE, or at least help define boundary conditions that could provide notions of a common field of ISE.

Similarly, SciComm is challenged to define itself as a field. On the last day of the 2018 Public Communication of Science and Technology (PCST) conference, the single largest international conference for science communicators, an audience member asked the conference organizers "What is science communication?" But no definition was forthcoming. Similarly, at an international meeting of science communication scholars and practitioners in Bellagio, Italy, in the fall of 2017, a discussion on whether SciComm is a professional field and what its boundaries are remained inconclusive. SciComm was identified as a composite field that is constituted or leans on more than a dozen other professional fields, including ISE, Communication Science, Media Studies, Social and Experimental Psychology, Linguistics, Science-Technology Studies, Marketing/PR, Cultural Anthropology, Political Science, History of Science, and others.

That is, despite having dedicated journals such as *Science Communication*, the field—which traditionally has included science journalism, communication science, and science communication officers working in science institutions—has its own struggles to understand its boundaries. Increasingly, by adopting principles of science engagement, some science communication professionals look a lot like ISE professionals. For example, the National Academies of Sciences, Engineering and Medicine's Koshland Science Center, once clearly an ISE institution, is being transformed by staff who have a SciComm rather than science museum background into an institution that focuses on community-based "pop-up program," i.e., science engagement events of varying content that are not only featured at the museum itself, but at various settings throughout the Washington, DC, area.

Partly in response to these developments, several efforts are underway to better define the field, including an *International Handbook of Science Communication*, currently in development and complementing the 2017 *Oxford Handbook of the Science of Science Communication*, the biennial Sackler Public Colloquia on Science Communication, and a new concerted effort by the National Academies of Sciences, Engineering and Medicine to organize professional standards and programs for the field. It is incontrovertible that the two fields exist: there are graduate degree programs, journals, and professional conferences that are labeled with one field name or the other, and there are many professionals who identify as belonging to these fields. However, the specific contours of the two fields, as well as who identifies or should identity with them, what their common or shared norms or practices are, and where and when professionals of the two fields meet is less obvious or defined.

Purpose of this study

The efforts that CAISE proposes to take in order to enhance connectivity and cross-pollination of ideas across these two fields are aimed at the intersection of ISE and SciComm (see Figure 1). Activities in the center of the overlapping ISE and SciComm spheres may be led by traditional ISE organizations such as science museums or science centers, or by institutions more commonly associated with SciComm, such as science research agencies or university divisions, public media companies or private producers of media, as well as newer, usually non-site specific organizations that stage live events for the public (e.g., science festivals that are part of the Science Festival Alliance, Guerilla Science, or Story Collider, etc.). In fact, many new or novel forms of science engagement now claimed by ISE are also overlapping with SciComm (Linett et al., 2014). We conjecture that exchange and collaboration at the intersection where the fields overlap can be productive for both, and may seed future collaboration that extends deep into the core of each field.

In order to both inform the efforts of CAISE to connect individuals and cross-pollinate ideas in the fields, as well as to track progress CAISE may make in achieving these goals, at the suggestion of its External Review Board (ERB), in 2017 CAISE proposed to conduct two studies that would establish a baseline state of connectivity. These include a bibliometric study, led by CAISE co-PI Kevin Crowley, and a social network analysis, led by co-PIs Martin Storksdieck and Bronwyn Bevan. CAISE PI Jamie Bell played an informant role in the design, conduct, and analysis of these studies. The results of the baseline social network analysis are reported here.

A social network analysis approach to understanding intersections between ISE and SciComm

To better understand the current relationship of ISE and SciComm, CAISE designed a study that used a blend of social network analysis and inductive methods from grounded theory (Glaser & Straus, 1967) as strategies for interpreting survey results that, at their core, asked individuals to name people or resources who influenced their work. The study is based on a social network analysis approach that specifically focused on a collection of so-called ego-network data from an extensive survey of practitioner and research leaders in ISE and SciComm.

At the core, the "ego" is a focal point in this study. "Ego" refers to a respondent who named others in the system (Kadushin, 2012; Wasserman & Faust, 2009). Linking who named whom and representing these relationships in a map creates what is referred to as an ego-network. Ego-networks differ from social networks in the narrow sense; the latter allow everyone in a network to express their relationship with everyone else in the network, something that can only be done when the group in question is relatively small. Ego-networks are a useful alternative to true social networks when 1) looking across domains (e.g., SciComm and ISE or

researchers and practitioners); 2) when the bounds of a network are unknown (as in this case: we do not know all of the people who work in ISE or SciComm) and 3) when the size of a network is so large that data collection for a true social network is impossible (Crossley, et al. 2015). All three of these limiting conditions apply in the broad ISE/SciComm system we were examining.

Many social network studies focus on an identifiable network (i.e. all members of a soccer league or all employees of an organization) where individuals have some sort of standing relationships, often with the goal to make improvements to the network (Valente 2012). Our aim is not direct intervention in a network, but rather a better understanding of how people currently share ideas and information within these loosely-defined professional communities of ISE and SciComm.

As described above, neither ISE nor SciComm are clearly or unambiguously defined or exhibit clear boundaries, and members of these professional fields might not self-identify as such, but identify primarily with professional fields that could be described as parts of ISE or SciComm, or simply with the institutions they are working for. In the case of ISE, those might be science centers, natural history museums, zoos, aquariums, or planetarium. In the field of SciComm, individuals might be science journalists, public information officers at academic institutions, or citizen science professionals. Therefore, rather than measure the strength or nature of the social connections of respondents, we consider the ties between respondents and the individuals they named as a proxy measure for flow of information and resources (Borgatti, et al., 2009).

By combining all the "ego" data from respondents through a snowball sample across domains, we set out to uncover key influencers within and across the ISE and SciComm communities. Mardsen (1990) refers to such "key influencers" as community "elites".

We use combined "indegree", the number of times an individual in the system is named by respondents, as our measure of relative influence (Carolan, 2014; Prell, 2012; Scott, 2000).

This approach has limitations. For example, many key influencers identified through a social network approach might not themselves complete the survey and therefore may not have had the opportunity to name each other or others they consider influential. Neither did they have an opportunity to reciprocate by identifying the respondent who named them. As such, this dataset does not lend itself to measures of network density, or centrality of individuals. It is easy to misinterpret the sociograms that result from this combined egocentric approach. Network structural holes, or dense cliques, may visually appear when none actually exist (Borgatti, et al. 2009; Crossley, et al. 2015). Therefore, it is critical to use only the social network metrics that are relevant to the available dataset (in this case indegree). Even with the given limitations, the combined egocentric social network approach used in this study is particularly helpful to provide rich detail about the movement of scholarship and experience through the system from the perspective of survey respondents. The maps also provide a visual stimulant for qualitative examination and development of deeper questions about the ISE/SciComm communities.

The goal of this study was to document the current state of connectivity between the fields, especially the relationships among people within and across the two fields of ISE and SciComm and the presence, source, and use of particular tools, resources, and strategies related to CAISE's high-priority areas of broadening participation, measurement and evaluation, and research and practice. Key questions of the study included:

- Which individuals (represented by associated ideas or bodies of work) are influential on individuals who identify as either ISE or SciComm?

- What professional resources (studies, reports, professional tools, and websites) do individuals who identify as either ISE or SciComm rely on for their work?

This report summarizes key results of the study. Earlier versions of the analysis helped to inform work of the two CAISE task forces, the Broadening Participation Task Force and the Evaluation and Measurement Task Force (see www.informalscience.org/caise-task-forces).

Furthermore, and together with an initial analysis of a bibliometric study on key characteristics of publications in SciComm and ISE, this study provides a rich foundation for CAISE leadership discussions around the degree to which SciComm and ISE are distinct from one another, and the actions CAISE can take to strengthen connectivity and cross-pollination.

The study also provided baseline metrics, collection of which was recommended by the ERB, that, if sampled again in several years, potentially provide significant evidence about (a) increased connectivity and interaction between the two fields that CAISE is intending to bridge and (b) whether the resources that CAISE develops through a task force strategy are being taken up and found relevant and useful by professionals working in those fields.

Bibliometric Analysis & Synthesis

In addition to this study, CAISE conducted a bibliometric analysis of ISE and SciComm research journals from 2012 to 2016.

Visit the following URL to read the analysis, as well as a synthesis of the findings from both studies:

bit.ly/baseline-studies

Summary of Methods

Survey sample

In order to generate ego-network maps and determine key influencers in ISE and SciComm, we constructed a questionnaire (see Appendix B) that recorded background information about respondents and asked them to name up to three individuals who influenced their work overall, as well as those who influenced their work in three key areas of interest to CAISE: broadening participation in STEM, research and practice, and evaluation and measurement, and one additional area: program design and implementation. Furthermore, respondents were asked to share resources and ideas that they rely on in their work in these four areas.

Sampling procedure and questionnaire

We limited ourselves to a sample of leading professionals in both fields. We recruited those who would likely have (1) agency over their work, (2) a professional interest in connecting to resources and individuals who could inform and enrich their work, and (3) established professional ties within and across fields as a result of their work. To establish this sample, we identified participants who had attended prominent professional meetings in SciComm or ISE, received relevant NSF funding, or took part in strategic publications that served to support their domain of research or practice.

To establish the ISE sample, we turned to current NSF AISL PIs and their colleagues who represented AISL-funded projects at the two most recent NSF AISL PI meetings. This group, by virtue of having succeeded at NSF panel review, was conjectured to have met the three sample criteria for inclusion described above.

We knew that some in this group (for example, some of the PIs of media projects) might identify also as belonging to the science communication field. Eliminating duplicates yielded 353 individuals.

To establish the SciComm sample, we identified individuals who participated in the following national leadership events related to science communication:

- Speakers at first (2012) and second (2013) National Academy of Sciences' Sackler Colloquium on the Science of Science Communication.

- (Co-)authors of the special issue of *Proceedings of the National Academy of Sciences* (PNAS) on the Science of Science Communication that resulted from the first Sackler Colloquium.

- Attendees of the 2013 meeting on the *Evolving Culture of Science Engagement* at the Massachusetts Institute of Technology.

- (Co-)authors of *The Oxford Handbook of the Science of Science Communication*.

- Members of the Board of the Public Communication of Science and Technology (PCST) network.

- Individuals who, at the recommendation of CAISE's External Review Board, were initially interviewed by CAISE to chart the domain of science communication.

Eliminating duplicates and individuals not likely to respond to the survey (e.g. celebrities, artists, out-of-field invitees) yielded 231 individuals who completed the full survey.

The two-step survey was administered to 657 individuals in ISE and SciComm, inclusive of both researchers and practitioners (i.e. designers, implementers and/or facilitators of experiences and settings). The combined total from each field was 584.

Overlap between the SciComm and ISE sample and lack of contact information reduced the sample further to 542 individuals who were asked to complete a questionnaire (see Appendix B: Survey Questionnaire) in the online survey tool Qualtrics. We sent four follow-up messages, including one personal request from a co-PI who had a relationship with the non-respondent. During a second survey wave we sent an additional round of invitations to 115 names solicited from the original respondents at the end of the survey. The total sample frame, therefore, was n=657 individuals, and yielded 231 responses, for a response rate of 35%.

Data analysis

We coded individuals and resources that were named by respondents according to the central ideas or theoretical traditions they advanced or developed. For instance, when Yale SciComm researcher Dan Kahan was named, we interpreted the influence to include ideas about the research field he most represents, i.e., "cultural cognition." When the long-time leader of the Science Museum of Minnesota, Eric Jolly, was mentioned, we interpreted the influence to include the ideas encapsulated (with Pat Campbell) in his writings about engagement, capacity, and continuity.

We analyzed responses to look for overlaps and differences between and across the two professional fields of ISE and SciComm. Additionally, reflecting CAISE's interest in strengthening connections between research and practice, we contrasted many of the responses provided by the four sector-role categories of ISE researchers, ISE practitioners, SciComm researchers and SciComm practitioners.

Finally, to inform our dissemination strategy, we inquired about respondents' familiarity with CAISE's website, InformalScience.org.

Using social network tools in the cloud-based open-source software called Kumu, we generated "maps" to visualize the complex data set that resulted from an online survey in Qualtrics and to reveal key players. To indicate an individual's influence, we utilized indegree (ID), a metric that counts the number of times an individual is named by others who participated in the survey.

As shown in Figure 2 and Figure 3 on the next page, each of the nodes (dots) on a map represents a person who responded to the survey. The size of nodes correlates with the number of times individuals were named as an influencer. Ties between nodes indicate that one person in the pair was named by the other. Arrows point from the person who responded to the person they named in their response. In some cases, the arrows appear in both directions indicating that the two individuals named each other. Size of nodes are an indicator, but not a direct measure, of the relative influence of an individual's work in the ISE/SciComm system of practitioners and researchers.
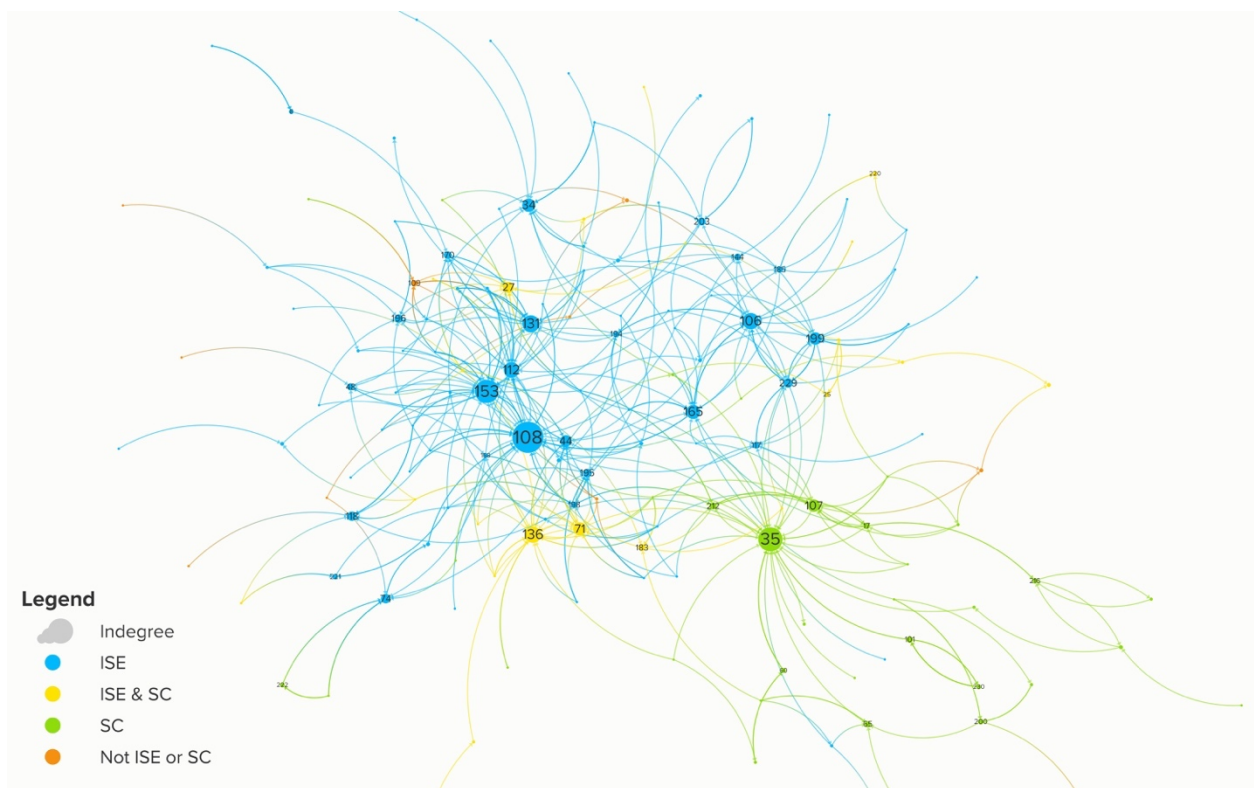
Figure 2. Map of the 231 respondents identified as ISE and SciComm. The larger the indegree, or more times a respondent was named by other respondents, the larger the node (dot) that represents them.
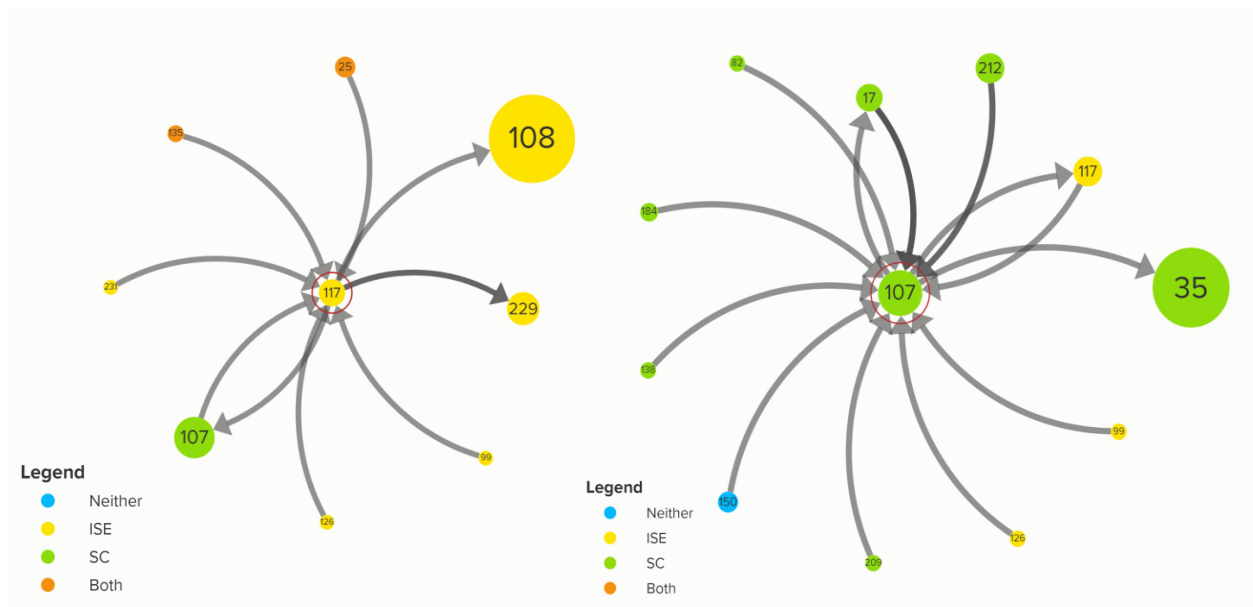

Figure 3. Sample maps focused on direct connections within the group of 231 respondents; #117 identified as part of the ISE community and has an indegree of 9, while respondent 107 identified as part of the SciComm community and has an indegree of 13.

The known ties to others in the dataset determine placement on the map. The 231 survey respondents named a total of 879 individuals as influencing their work, 95 of whom were survey respondents (see Figure 4). While the positioning within this open network should not be over-interpreted, we can still see through few steps, key influencers are connected directly or indirectly with one another and can potentially impact a broader set of individuals beyond their direct connections. Such individuals can leverage their connections to leverage and disseminate ideas into a community.

One of the values of these maps lies in understanding the potential for flow of information, based on the notion that Person A, who is informed in their work by Person B, might inform Person C about Person B if Person C names Person A as influencer.

The open map of the 231 respondents can also form the foundation for tracking change within what could now be considered a potentially closed network. That is, a repeat of the survey, with just the 231 current respondents and a response rate of over 80%, could provide indication for better connectedness and information flow between ISE and SciComm, but also research and practice, as well as track the degree to which CAISE activities might have contributed to potentially stronger connections between communities. This latter would require coding resources listed as to whether they were generated by or provided through CAISE, or the inclusion of closed-ended items around awareness, use, and utility of CAISE resources.
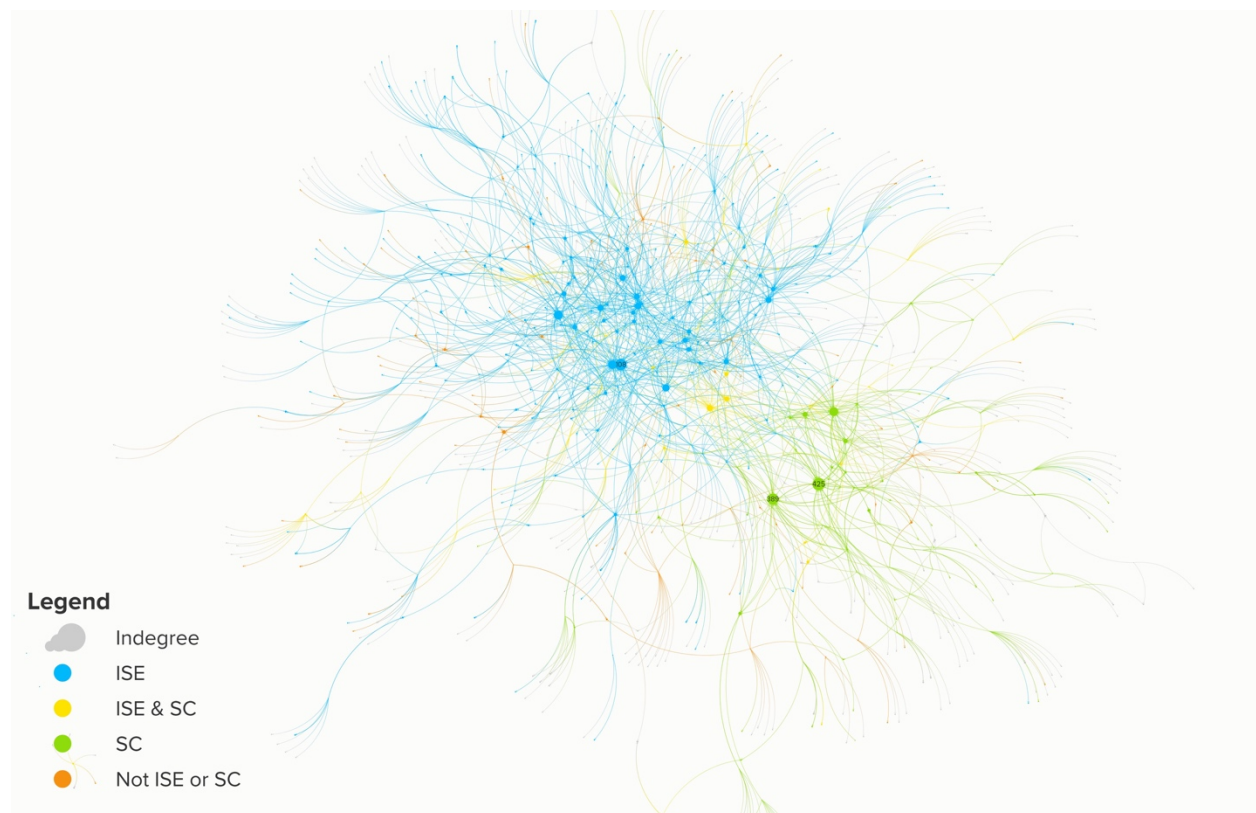

Figure 2. Map of all 1015 individuals (231 who responded and the 784 additionally named).

A word of caution is needed here, though. Since the basis of these maps are individuals naming those who might have influenced their professional work, it does not represent a social network of reciprocal professional ties that individuals nurture and sustain. Therefore, interpretation of the network maps is not based on degrees of centrality or isolation. Instead, the network maps illustrate the roles and sectors of individuals whose work serves to inform or inspire the work of the 231 respondents.

We analyzed responses about influential resources through an iterative coding process that began with identifying the type of resource (e.g., website, report, journal publication, or professional tool such as an observational rubric) and then coded each resource for content (e.g., whether evaluation instruments were ad hoc, published, or based on published instruments). Two researchers coded all resources, with iterative discussion until coder agreement was attained. We then contrasted results between respondent type (ISE/SciComm, researcher/practitioner, and in some cases between ISE-R, ISE-P, SciComm-R, and SciComm-P).

Limitations and future directions

Social network analysis techniques are usually used in "closed" networks of individuals, where all known members are included, and high rates of survey participation are required (see discussion above). As mentioned, due to the large and somewhat amorphous nature of the fields we were studying, we were not able to, at baseline, identify a comprehensive and closed professional group (e.g., all those "in" ISE or SciComm), nor did we desire to. As such, the social network analysis visualizations do not account for all the possible ties within the group, only the ties that responders named as most significant in the specific areas addressed in the survey.

Survey respondents could name an influential individual based on a personal relationship, a strong professional or academic overlap, or because they were high profile and well known, whether or not they were "in" the same community of practice. This approach, called ego-network analysis, does not require a high rate of survey participation. As described earlier, ego-networks are exploratory and suggestive. The resulting respondent sample of 231 individuals, however, now constitutes an established "network" that can be used in future social network analyses with more traditional "closed network" techniques.

Another limitation of the study lies in the nature of the questions. We asked respondents to name the most influential individuals and resources they used in their work. In order to limit the burden for respondents we did not ask about how the named individuals contributed to their work or the nature of the influencers. A repeat study with a more limited set of questions and a deeper exploration into the nature and uses of influential people and resources is now possible with the resulting sample of 231 respondents from this study.

Summary of Findings

In the following, we highlight key findings of the study. Detailed results are featured below in the Results section.

The study created a rich data set that CAISE will be able to tap into for the coming years, though this report can only cover key results and findings. The study also generated a sample frame of 231 individuals—comprised of two thirds ISE and one third SciComm, and about half practitioners and half researchers—that can form the foundation for a future impact study on how CAISE impacts its key constituency. *This suggests that a similar study with a stronger focus on the impact of CAISE work could be conducted in a few years, with the respondents of this study as an indicator population for the typical CAISE constituency, at relatively little cost and as part of a pre-post summative evaluation of CAISE.*

Data suggest that the communities of ISE and SciComm are still quite distinct: few researchers in one community named researchers or resources from the other community as influential on their work. Similarly, few practitioners named practitioners from the other field as influential on their work. This finding is corroborated by the bibliometric analysis, which found distinct and different patterns in the content of academic publications between ISE and SciComm based on occurrence of salient terms in these publications. *This suggests that there are unrealized opportunities for cross-pollination in areas such as broadening definitions of what counts as "science learning" (e.g., NRC, 2009) or in connecting risk perception and decision-making (von Winterfeldt, 2013).*

Practitioners in general have less visibility in both fields. Both practitioners and researchers, across both fields, were more likely to name researchers as influential to their work than they were to name practitioners. This may be due to our sample selection, which is linked to (a) success in writing NSF proposals for AISL PIs, and (b) participation in leading national conferences where the work of

researchers is often highlighted. *This result suggests a need for CAISE to organize professional learning activities in ways that more prominently highlight the work of practitioners in ways that are seen as relevant and salient to the work of both researchers and practitioners across the fields. This is important insofar as research results from peer-reviewed journal articles only broadly suggest what practitioners may do as a result of a study, but can't address how practitioners should implement recommendations for practice.*

Researchers in SciComm named fewer individuals in the area of broadening participation than did ISE researchers, ISE practitioners or SciComm practitioners. The research literature that SciComm researchers draws on was more likely to focus on marketing and communications than on work related to equity, participation, and learning. *These results indicate that existing work on broadening participation in ISE might be of value to SciComm, which is developing a strong awareness of the need to address these issues, primarily because of conversations around reaching new audiences.*

Custom-made assessments are far more commonly used than published ones in both fields. Much research and evaluation, therefore, relies on ad hoc approaches in order to align measures to project-specific goals or outcomes. However, the use of blended approaches, whereby published instruments are adjusted to fit specific needs, suggests an awareness of the usefulness of tapping into existing and potentially validated measures, but also hints at the ongoing need to ensure that the measurement fits the needs of a particular project. *This suggests an opportunity for CAISE to more prominently disseminate existing shared measures on constructs common to both fields (such as science interest, science identity, and science engagement), and to further a community discourse on the utility and limits of using existing validated measures for common outcome constructs.*

Practitioners rely heavily on research syntheses and similar forms of digested information rather than on primary research and evaluation literature. *This result validates previous insights into the limit of peer-reviewed research articles as direct sources of professional knowledge for practitioners. "Original literature" is rarely physically accessible to practitioners, but more importantly it is not written to be understood or interpreted by practitioners, nor is much research designed to immediately provide guidance for practice. The result suggests a need for CAISE to focus on producing or disseminating translational research resources for practitioners, in addition to maintaining physical access, through EBSCO databases, for those practitioners and researchers who do seek direct access to primary sources of research.*

As part of this study we inquired about respondents' familiarity with, and use of, InformalScience.org. Almost all ISE respondents and about half of the SciComm respondents were familiar with CAISE, and about a fifth of the ISE respondents use InformalScience.org frequently (defined as at least once a month). Most report visiting occasionally (i.e., several times a year). *This suggests that the website is an as-needed resource for leading professionals in the field, but that CAISE could work to raise its profile among SciComm leadership.*

Detailed Results of the Study

Who responded?

We received 231 surveys with an effective response rate of 35%. As intended, most (74%) of respondents said they had been in their field for 10 or more years, and only 4% were in the field for fewer than five years.

Reflecting our awareness of the fluidity of the fields, we asked respondents to categorize themselves by role and sector. On a 5-point scale, respondents rated whether they identified as more ISE or more SciComm (or as someone in between). On the same 5-point scale, respondents also rated whether they identified more as a researcher or as a practitioner.

In all, 199 respondents categorized themselves, while 32 respondents were assigned to categories, given personal knowledge of the respondents by the research team. In nine cases of those 32 cases, the research team altered the self-classification of respondents (mostly when those self-identified as "both" or "neither"), based on the research team's familiarity with respondents' work.

For example, when a tenured professor and accomplished researcher at a university classified themselves as equally researcher and practitioner, we changed their status from "both, researcher and practitioner" to "more researcher than practitioner."

One respondent only completed 25% of the survey, and those data were not included in the final tally (reducing the effective tally of respondents from 232 to 231).

As shown in Table 1, 44% of respondents identified primarily as practitioners, and 38% primarily as researchers; about 15% placed themselves in the middle of a 5-point continuum (nine saw themselves as neither). Half of the respondents identified as ISE, 27% as SciComm, 14% saw themselves in the middle, and about 9% identified or were identified as neither (most in the "neither" category had not responded to the questions and were subsequently assigned).

The 231 survey respondents named altogether 784 individuals who did not themselves answer the survey. In addition, 95 named individuals were part of the original 231 survey respondents. In all, 879 (95+784) individuals were named, and 1015 individuals were included in the study (231 survey respondents +784 individuals who did not answer the survey but were named by respondents).

	Researchers	Practitioners	Both	Neither	Total
ISE	47 (20.3%)	51 (22.1%)	18 (7.8%)	0	116 (50.2%)
SciComm	27 (11.7%)	28 (12.1%)	6 (2.6%)	2	63 (27.3%)
Both	9 (1.7%)	18 (7.8%)	9 (3.9%)	1	32 (13.9%)
Neither	9 (3.9%)	4 (1.7%)	1	6 (2.6%)	20 (8.7%)
Total	87 (37.7%)	101 (43.7%)	33 (14.7%)	9 (3.9%)	231 (100%)

Table 1. Respondents by Role and Sector

Note: In order to assign individuals to a field (SciComm or ISE) or role (researcher or practitioner) we condensed the 5-point scale to 3 points, counting those who trended more towards one in just one category. Few individuals did not fit either format.

Influencers identified by respondents

We asked respondents to name 1-3 individuals whose work they turn to in five distinct categories: (1) generally, (2) broadening participation, (3) evaluation and measurement, (4) staying current with research and (5) staying current with design and implementation. Each of the 231 respondents thus had the opportunity to provide 15 names (three names for each of the five categories, making the total possible number of provided names 3,465, or 693 per category).

Some 2,086 namings occurred (with repetition of individuals), with 879 unique individuals named in all. There was a bimodal distribution of the number of people named by respondents. On the lower end of the spectrum, four names was the most common number of individuals named, while on the higher end of the spectrum, ten was the most common number of individuals named (see Figure 5 for the distribution). Respondents who classified as belonging mainly to the ISE sector named significantly more individuals than those classified as belonging to the SciComm sector (9.4 vs. 7.1, $p<0.001$). This difference might indicate that there are a greater number of influencers in the ISE sector, or it could mean that ISE respondents spent more time completing the survey.

The table in Appendix A shows the degree to which respondents provided answers to the question of whose work they turned to in their professional lives in general, or within the four other listed categories. Of the 696 namings that resulted from this question, respondents were most inclined (89%) to provide names in the overall or general category. Research followed with 62%, and the categories broadening participation, design and implementation, and evaluation and measurement trailed around 50%. Overall and slightly more than predicted by participation, ISE Professionals provided 57% of all names, versus 23% by SciComm professionals; individuals in the "both" or "neither" categories provided another 20%. Names provided by researchers and practitioners were nearly equal (40% versus 42%, respectively), roughly in accordance with participation.

Of the 879 influencers named, 784 were not survey respondents; they had either not been included in the sample or did not respond to requests to complete the survey. Ninety-five of the 879 influencers had been identified in our sample and completed the survey. Since most who were named as "influencers" did not themselves complete the survey, to identify their sector and role, research team members relied on their knowledge of these individuals or conducted online research to make an assignment.
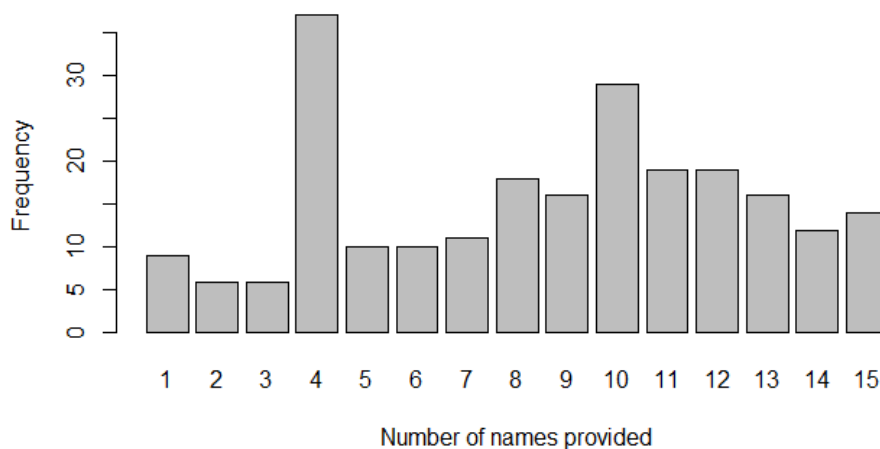

Figure 3. Distribution of the number of names provided by respondents

When the identity of a named person was unknown or ambiguous, no assignments were made[1]. Because we were only able to unambiguously assign half (i.e., 440 of the 879 unique individuals named) to either sector or role, reporting out the distribution of the individuals named by sector or role might be misleading and prone to misinterpretation since we cannot estimate the bias in the unknown individuals.

We hypothesize, though, that due to the research team's stronger expertise in informal and afterschool STEM, the group of unidentified named individuals might be biased towards SciComm and those who do not fit either category. Since we had more ISE than SciComm respondents provide names, we will weigh the numbers further to take the uneven sample composition into account.

Note that this limitation did not apply to the group of individuals who were named multiple times (key influencers) since they were also more likely to be identified and we will discuss them below.

Table 2 provides the role and sector of individuals named as influencers in each of the five possible categories. Note that we were only able to establish the sector and role for about half (n=445) of the individuals named. Individuals named as influencers, and identified by either the research team or a survey respondent, were most likely to come from the ISE sector.

While about 50% of respondents identified as mostly ISE, approximately 60 percent or more of the individuals named were classified as from ISE. ISE individuals are therefore overrepresented as influencers, considering that about 50% of the survey respondents identified as ISE.

	SECTOR				ROLE			
	ISE	SciComm	Both	Neither	Researcher	Practitioner	Both	Neither
General (n=242)	61%	14%	7%	19%	58%	34%	5%	3%
BP (n=136)	65%	15%	5%	15%	46%	44%	8%	1%
Design (n=154)	71%	9%	8%	12%	44%	45%	9%	1%
Eval (n=115)	63%	17%	8%	13%	79%	16%	5%	0
Research (n=159)	59%	13%	6%	21%	85%	11%	4%	0
Total (n=445)	61%	13%	6%	21%	58%	34%	6%	2%
Sample (n=231)	50%	27%	14%	9%	38%	44%	15%	4%

Table 2. Number of influencers named, by sector and role, for each category

Note: *Percent sector and role is provided for a total of 445 individuals that were named as influencers, which is approximately half of the total of 879 total influencers named. Sector and role are unknown for the other individuals. Role and sector of the sample is provided for comparison as the approximate percentages that might be expected in each category based on the role and sector of those providing the names.*

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[1] It was possible that those named were neither ISE nor SciComm, but hailed from different professional backgrounds, such as formal education, developmental psychology, etc.

In contrast, 27% of the respondents identified as SciComm, yet 13% of individuals named as influencers and who could be assigned to a sector were identified within the SciComm sector. SciComm influencers might therefore be underrepresented in our sample. The same pattern holds for those who identified as both ISE and SciComm. On the other hand, while 9% of the respondents identified as neither ISE nor SciComm, 21% of influencers fell into the category of "neither," suggesting that individuals in both fields are looking beyond their boundaries for support.

For role, researchers made up 38% of the survey respondents, but represented 58% of named influencers, while practitioners represented 44% of respondents, yet were 34% of those named as influencers. Individuals named as influencers were most likely to be researchers in the categories of general, measurement and evaluation, and research, but there was a fairly even split between researchers and practitioners being named in the categories of broadening participation and design and implementation. The researcher dominance, therefore, seems to be limited to domains of specific expertise. The stronger prominence of practitioners in the areas of broadening participation and design and evaluation might indicate the complexity of the area, difficulty of translating research results into application, or the higher appreciation for "wisdom from practice" in these areas.

Who are key influencers overall across all categories?

Of the 879 individuals named, 533 were named one time, and altogether 65 were named six or more times by survey respondents across all 5 categories (ID≥6), and are classified here as "key influencers" (see Figure 6, below). The threshold of six was determined by visual analysis of a histogram of frequency of namings for those individuals who were named (similar to a Scree Plot Analysis).

However, we acknowledge that the threshold could be set differently. In fact, just 16 of those individuals received 15 or more mentions across all categories. Who are the people who are named a lot, and thus could be considered to have strong influence on the fields of ISE and SciComm?

The most influential person (ID=40) was a science communication researcher. The other individuals who were often named as influencers (in order of greatest mention to fewer mentions) were an ISE researcher (ID=37), SciComm researcher (ID=35), an ISE researcher (ID=28), a SciComm researcher who we know has strong ties to ISE (ID=28), another ISE researcher (ID=27), and an ISE practitioner who we know played a considerable role in influencing research and evaluation (ID=22).

Overall, prominent individuals who were named 15 times or more tended to be named predominantly or even exclusively by their sector (ISE or SciComm), with only one notable exception. The same individuals, however, were often split between the roles of researcher and practitioner in terms of being mentioned by respondents to the survey.

Another characteristic of the individuals who were named most often is that they either publish prominently, and/or are associated with national-scale projects that themselves might be considered influential in their field.
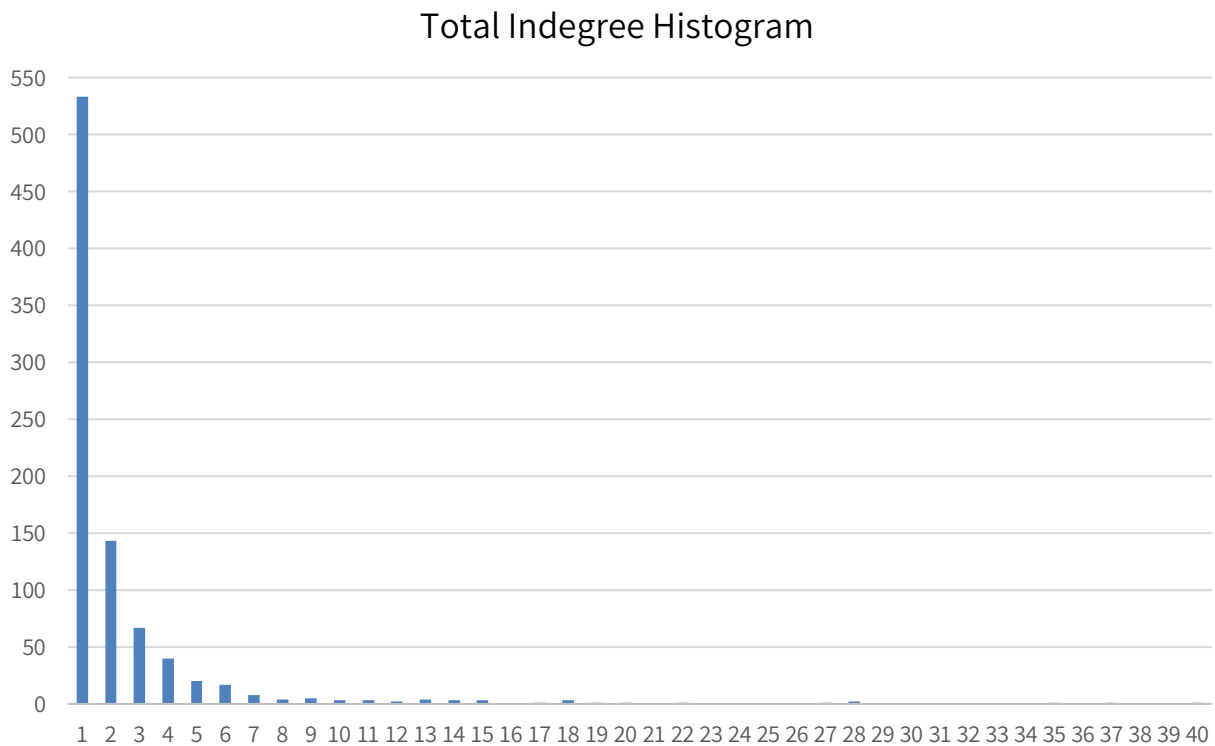
Total Indegree Histogram

Figure 4. Distribution of influencers. The person who was named most across all categories received a total of 40 mentions (ID=40). Note that just 65 individuals received six or more mentions.

Network maps provide an initial sense of how potentially separate ISE and SciComm sectors might be with respect to ideas and discussions. As discussed above, the maps do not necessarily represent information on who influences which field in what ways; however, they nonetheless provide a rough indication as to whether ISE and SciComm individuals (as representatives of ideas and perspectives) are distinct from one another or blend across sectors. The former would indicate less intellectual exchange between ISE and SciComm, the latter more.

As Figure 2 and Figure 4 suggest, at this point in time, the named individuals who represent respondents and the named individuals who represent all the persons in our sample visually separate out into an area represented mostly by ISE and an area represented mostly by SciComm, with those who are identified as both somewhere in between. These two maps represent the idea that at this point ISE and SciComm are quite distinct communities.

On the other hand, the separation between the roles of researchers and practitioners is less pronounced (see Figure 7). We can, however, identify two relatively distinct clusters of researchers (in green) that represent ISE (top) and SciComm (bottom).
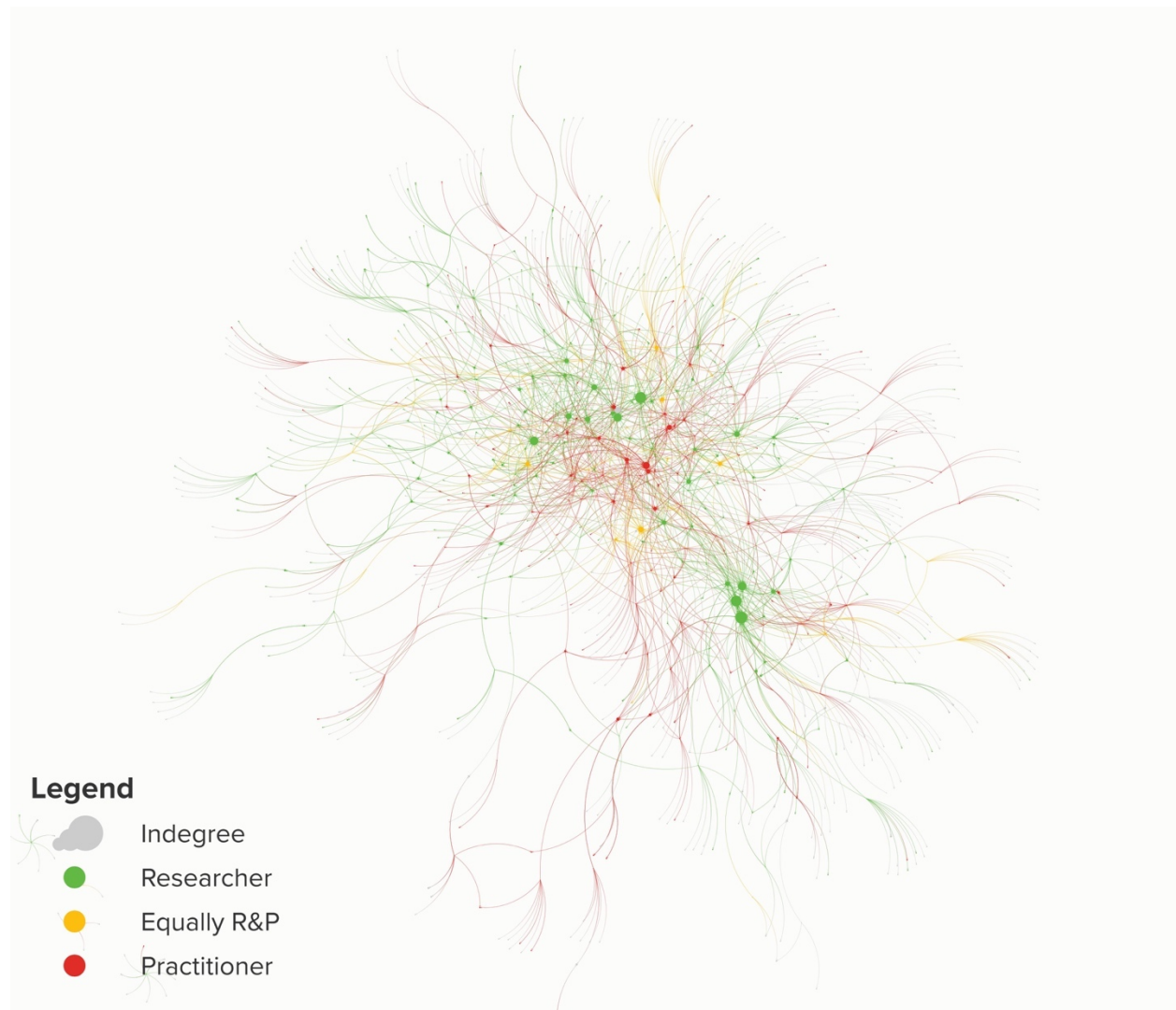

Figure 5. Open network map of all individuals by role.

Who are key influencers in broadening participation?

Broadening participation in STEM is a significant priority for the NSF AISL community and for CAISE. Many organizations are undertaking programs, creating positions, and participating in efforts to build their capacity towards inclusivity and to work with and for historically underrepresented populations in STEM.

We sought to understand who the respondents turned to for ideas or guidance in their efforts to broaden participation, as well as to gauge the relative awareness or involvement of each sector-role in broadening participation.

As Figure 8 indicates, 52 individuals received more than one mention in the broadening participation (BP) category.

The maximum number of mentions (ID=12) was received by a science education researcher with strong ties to ISE who had done extensive work in BP. Only ISE respondents, most of whom identify as researchers, mentioned this person. In contrast, the person with the second-highest mentions or indegree (ID=11) was a practitioner in the ISE sector with a long history of active work in BP. ISE or ISE/SciComm respondents, largely identified as practitioners, also mentioned this person.

With the exception of one celebrity SciComm person, mentioned a total of five times, all remaining 51 individuals with more than one mention in BP were classified either as ISE or in being at the boundary between ISE and SciComm. The data suggests that ISE may have relatively more resources in terms of individuals to address BP-related issues.

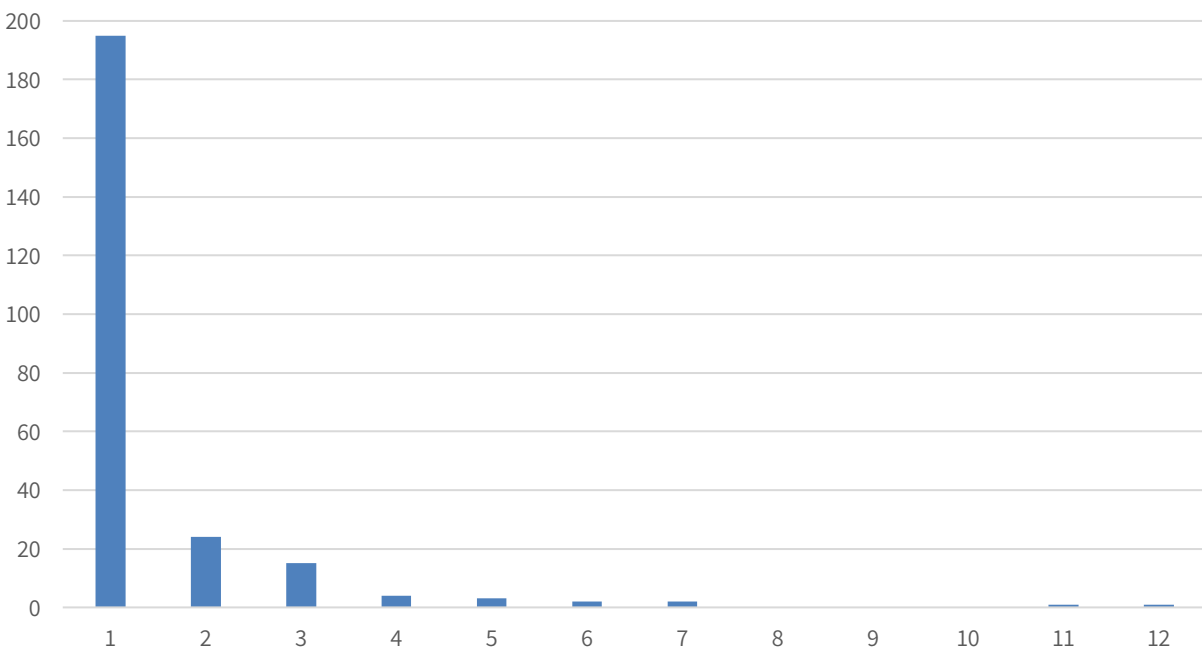## Indegree Broadening Participation Histogram

Figure 6. Distribution of influencers within the domain of broadening participation. Altogether, 52 individuals were mentioned more than once. The person who was named most across all categories received a total of 14 mentions (ID=12).

Network maps within the domain of broadening participation

Figure 9 illustrates the network of influencers that emerges within BP. ISE professionals dominate the domain of broadening participation, but this figure also shows a considerable degree to which individuals are in the periphery. That is, few (or only one) individual mentioned them, and the way they were mentioned suggests that their influence might be local, or limited to few people and without "cascading effect."

Individuals mentioned in a way that seems to embeds them deeply into this open network are those whose ideas might more easily spread—

although our research design did not specifically address the way in which information flows across individuals.

Figure 10, on the next page, is a different form of representing network data. It shows three degrees of naming for the most mentioned individual within the domain of broadening participation (the person labelled as number 276); that is, it shows an ego-network for that person which helps us understand how this person might not just influence the individuals who named 276, but how the potential influence of individual 276 radiates out into a professional community.
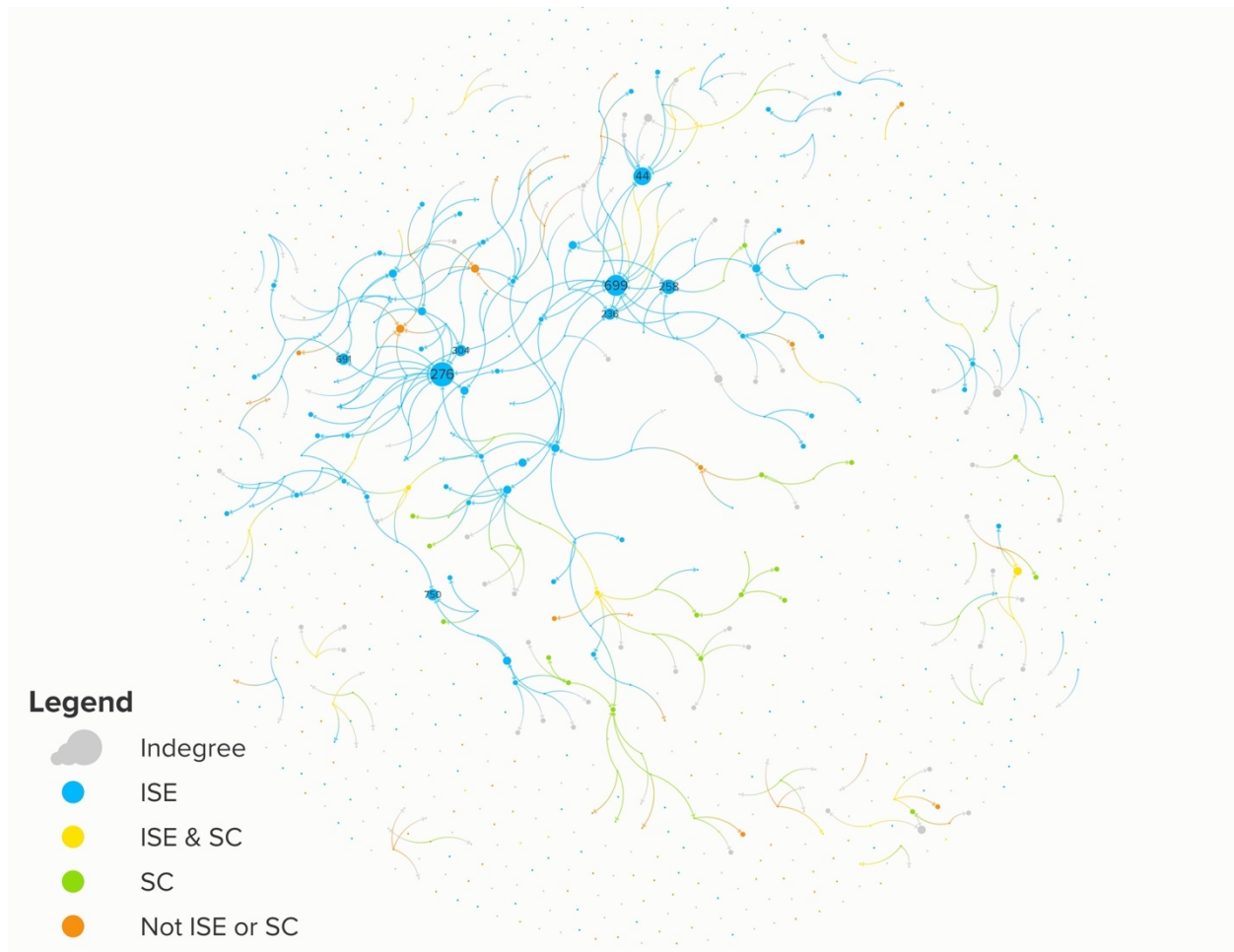

Figure 7. Network of all individuals mentioned as influential by respondents to the survey, within the domain of broadening participation, by sector. The size of the dot represents indegree (number of mentions); arrows indicate direction of mention. SC = SciComm.
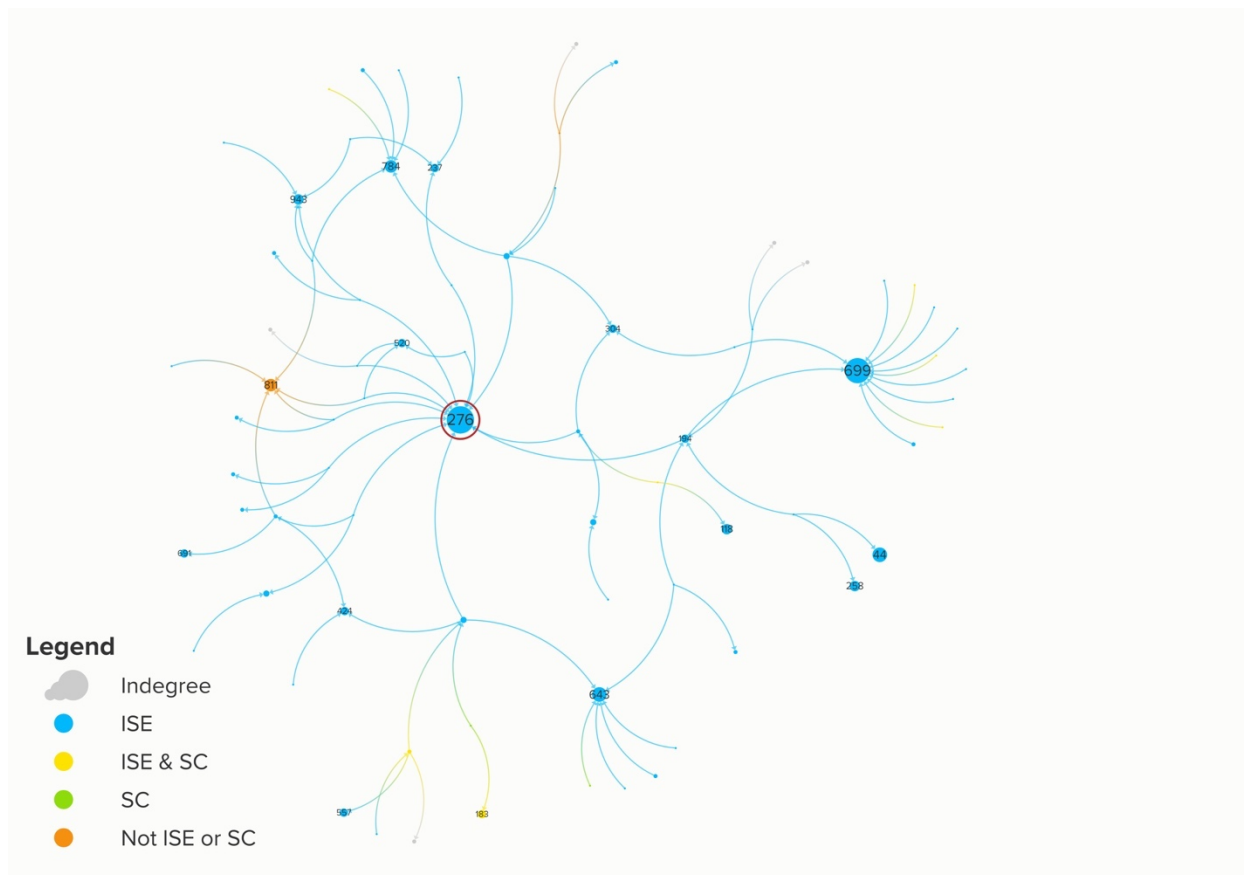
Figure 8. 3-degree network map of the individual most mentioned as influential by respondents to the survey within the domain of broadening participation, by sector (276). The size of the dot represents indegree (number of mentions); arrows indicate direction of mention. SC = SciComm.

The network around this ISE researcher again shows the dominance of ISE individuals, but also illustrates the connection to the second-most named individual (699). As described above, individual 276 is a researcher who is relatively new to ISE, while 699 is a practitioner who played a leading role in BP within the science center field. Only one person, however, named both individuals.

The map also features one person who classifies as neither SciComm nor ISE (811). This person is a natural scientist known for innovative approaches to broader impacts, focused on underserved populations. Individuals 276, 699 and 811 did not complete the survey, so we do not know whether they might have mentioned each other.

Nonetheless, detailed ego-maps like this can tell us about key influencers, and suggest whom CAISE may want to involve as ambassadors for CAISE resources into their respective communities.

Resources for broadening participation

Respondents were asked whether their "work intentionally focused on broadening participation in the STEM fields or in the areas of science communication or informal STEM education." Of the total number of 197 respondents, 161 (82%) answered in the affirmative, although there were clear differences between respondents who identified as ISE or ISE/SciComm and those who identified only as SciComm (Table 3, next page).

	Addressing barriers to access	Changing participant recruitment & retention	Co-designing with underrepresented audiences	Building partnerships	Changing hiring & staffing practices	Changing programming to appeal to underrepresented audiences
All (n=161)	32%	20%	34%	57%	8%	24%
ISE (n=91)	34%	16%	37%	64%	5%	21%
Practitioner (n=38)	42%	11%	42%	68%	3%	13%
Researcher (n=37)	32%	24%	27%	59%	8%	24%
SciComm (n=37)	22%	32%	27%	43%	16%	27%
Practitioner (n=19)	16%	32%	21%	47%	21%	37%
Researcher (n=13)	31%	46%	31%	38%	8%	8%
Practitioner (n=78)	35%	19%	33%	60%	9%	23%
Researcher (n=53)	32%	30%	28%	51%	8%	21%

Table 3. Which two primary approaches or strategies do you use for broadening participation?

The former two categories yielded an affirmative response rate of 90%, while the latter was 65%. Ninety-three percent of ISE practitioners, 88% of ISE researchers, 76% of SciComm practitioners, but only 52% of SciComm researchers supported the statement.

The 161 respondents who indicated that their work entailed efforts to broaden participation were asked to choose two primary approaches from a list of six options (see Table 3). "Building partnerships" was the most cited strategy, with 57% across all respondents (and favored more by practitioners than by researchers), followed by "co-designing" and "addressing barriers", which were mentioned by a third of respondents. Across all sector-role types, changing hiring and staffing processes was the least (8%) cited strategy. There were some notable differences between respondents from ISE and SciComm. Building partnerships was less prominent amongst SciComm respondents (43% versus 64% for ISE); in contrast, changing recruitment (32% vs. 16%) or hiring and staffing practices (16% vs. 5%) were more prominent amongst SciComm than ISE professionals. This suggests an area where the respective fields might learn from one another.

Respondents were asked to describe resources they used in their work on broadening participation. The answers to the open-ended question were subsequently coded (n=122 codes) for major types of resources. Program models were most often mentioned by ISE respondents (39%), and people were most cited by those who identified as SciComm or SciComm/ISE (30%).

Original research was cited by about 18% of respondents (irrespective of their professional field), followed by general references to a body of work and translational research. The former may have been slightly favored by SciComm (14% vs. 10%), while the latter was favored by ISE respondents. Practitioners for the most part referenced program models (47%) and people (27%) while researchers, not surprisingly, referenced original research (24%) and general bodies of research (20%).

Slightly fewer than half of resources cited, by both ISE and SciComm respondents, reflect "committed" perspectives, that is, specific theoretical orientations, for example participatory research. Researchers were more likely to cite "committed perspectives" than practitioners (56% vs. 36%), while practitioners preferred "practical" approaches, such as using specific marketing approaches to reach new audiences, more than did researchers (32% vs. 20%).

Who are key influencers in research and scholarship?

As Figure 11 indicates, 53 individuals received more than one mention as being influential in the category of research and scholarship. The maximum number of mentions (ID=18) was received by an ISE researcher who was mostly mentioned by ISE respondents, and also was split between researchers and practitioners.

The second-highest mention (ID=17) went to a SciComm researcher with high national visibility. This person was mentioned mostly by SciComm respondents, and was also equally mentioned by researchers and practitioners. In fact, the nine individuals named more than 5 times in research and scholarship consisted of five ISE and four SciComm individuals. In each group there was one "bridge" person, that is one ISE person with relatively strong ties to SciComm, and one SciComm person with relatively strong ties to ISE.
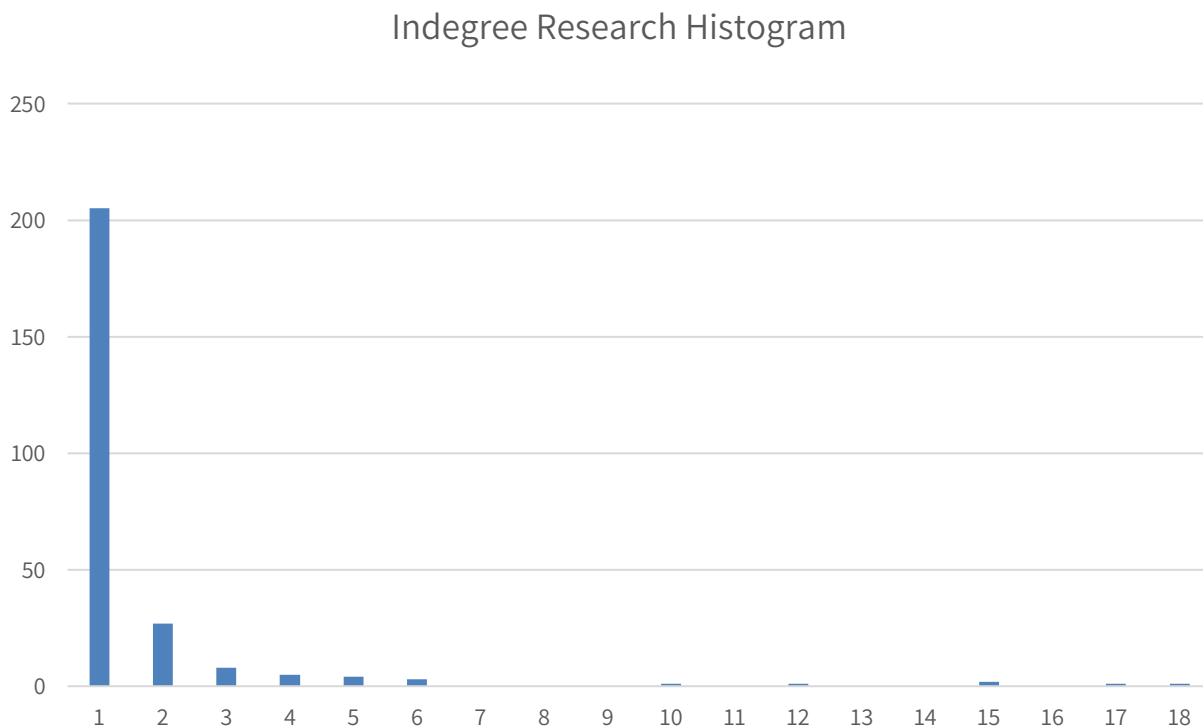
Indegree Research Histogram

Figure 9. Distribution of influencers within research and scholarship. Altogether 53 individuals were named more than once. The person most-named within this category received 18 mentions (ID=18).

Network maps within the domain of research and scholarship

Figure 12 maps the network of influencers who emerge within research and scholarship. It shows a distinct pattern between ISE and SciComm, with ISE respondents contributing to the high-mention individuals in ISE, and similarly in SciComm. SciComm researchers are frequently mentioned despite a far lower relative number of SciComm respondents; for instance, the SciComm individuals 425 and 389 have IDs that are equal to the ISE individuals 108 and 153 despite far fewer SciComm respondents. Most importantly, though, only a small number of individuals name both prominent ISE and prominent SciComm researchers. This current lack of joint naming indicates the possibility for enlarging the "bridge" between the scholarship in ISE and that in SciComm, i.e., increasing the number of individuals who lean on research in ISE and in SciComm.
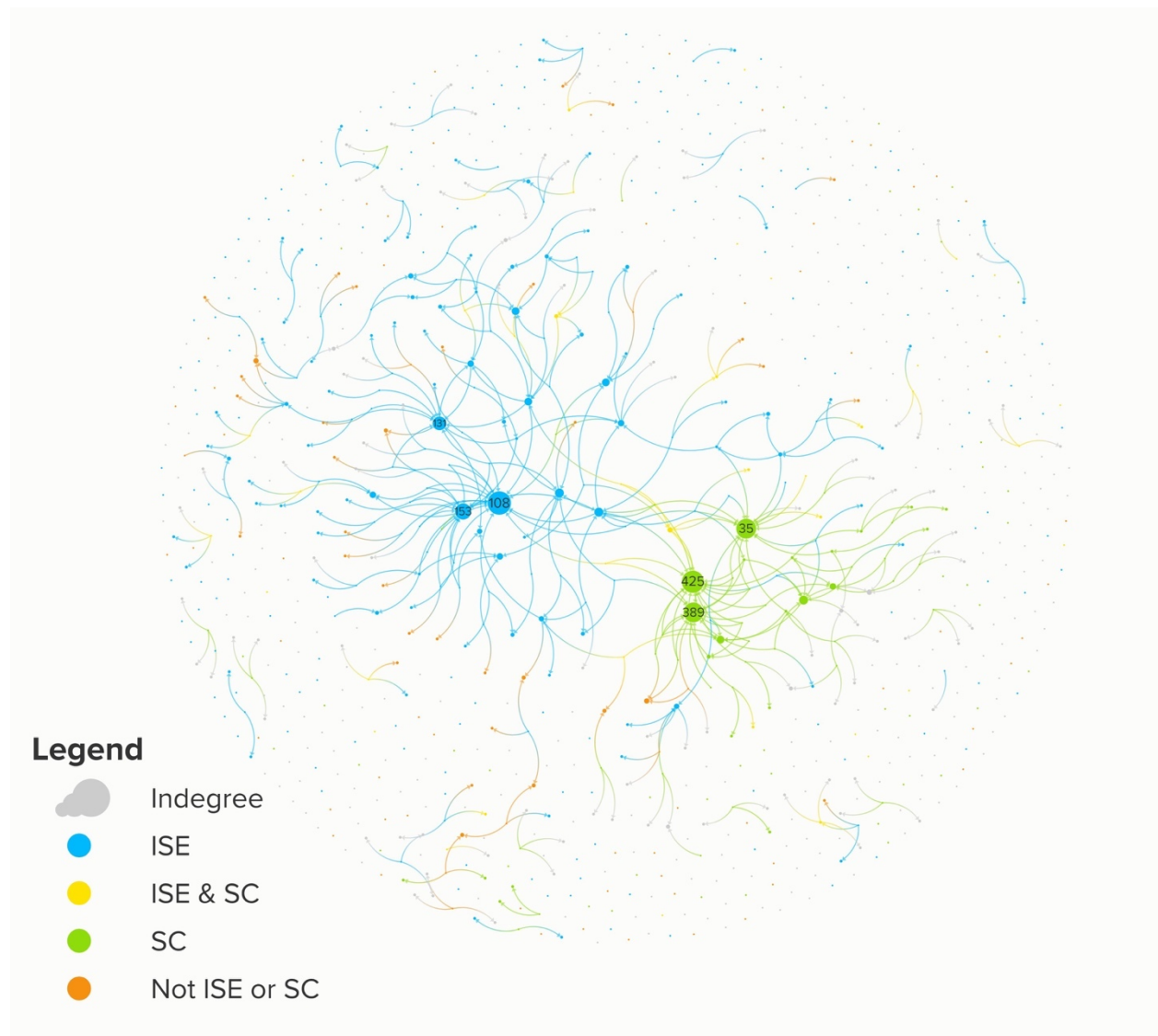

Figure 10. Network of all individuals mentioned as influential by respondents to the survey, within the domain of research and scholarship, by sector. The size of the dot represents indegree (number of mentions); arrows indicate direction of mention. SC = SciComm.
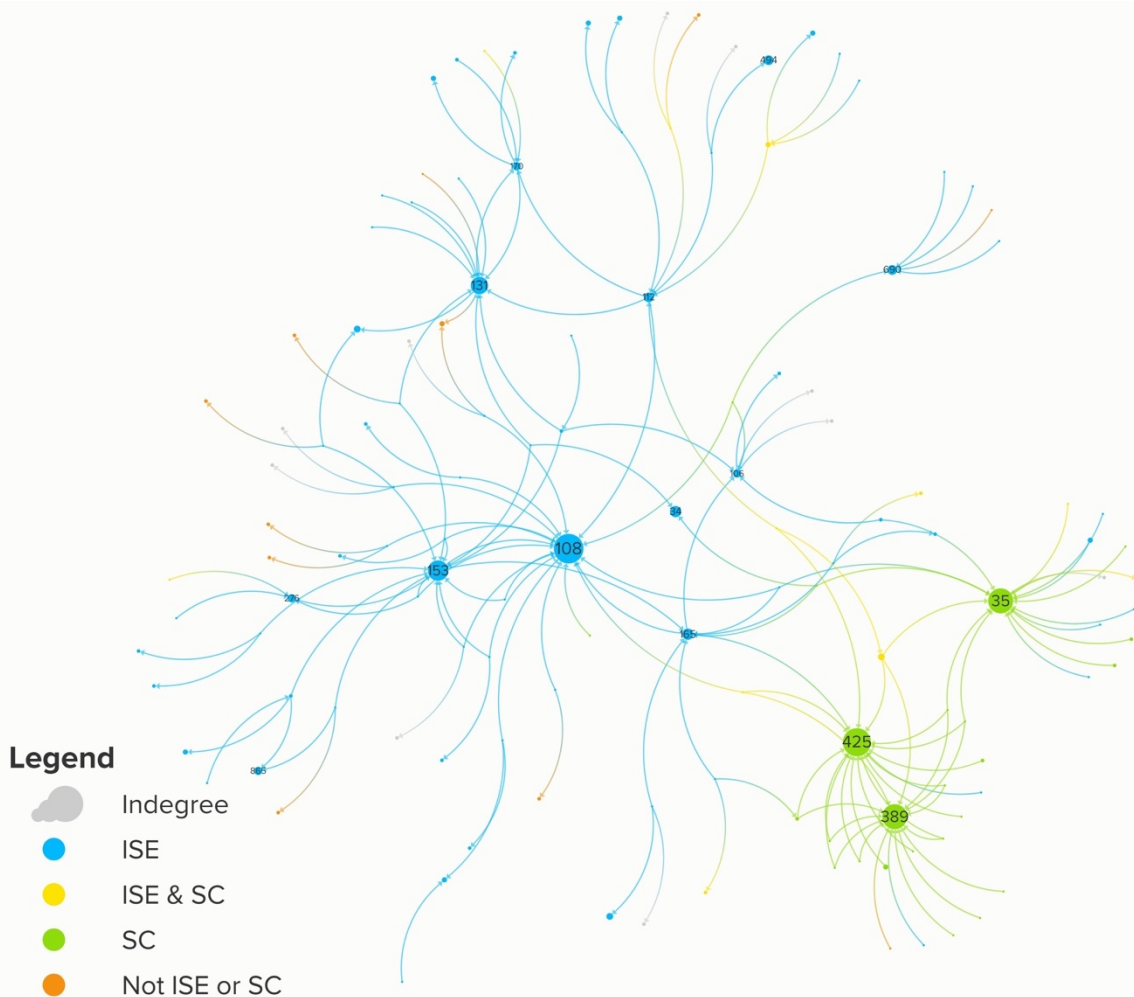
Figure 11. 3-degree network of the individual most mentioned as influential by respondents to the survey within the domain of research and scholarship, by sector (108). The size of the dot represents indegree (number of mentions); arrows indicate direction of mention. SC = SciComm.

Figure 13 details the 3-degree (of separation) map of the most-mentioned individual in research and scholarship, an ISE researcher (108). The map shows that while the top-named SciComm researchers are included in this 3-degree map, very few individuals connect what appear to be distinct clusters of individuals and, by extension, possibly clusters of ideas. A future map might exhibit more individuals who rely on the scholarship of individuals 425, 389, 35 and 108; that is, if ISE and SciComm became more integrated, scholarship from both sides might both begin to influence individuals.

Resources in research and scholarship

The vast majority of respondents (85%) affirmed that they tried "to keep up with emerging or innovative approaches to either science communication or informal STEM education research" (Table 6). Practitioners in our sample scored surprisingly high (78%) on this question (94% of researchers responded affirmatively to the question, which was expected). ISE professionals rated themselves higher than SciComm professionals (91% vs. 79%).

The vast majority of respondents (90%) also affirmed that they "try to keep up with emerging or innovative approaches to either science communication or informal STEM education practices." However, the trend here was reversed: practitioners were more likely to agree with the statement than researchers (96% vs. 80%), and SciComm researchers seemed least interested in staying updated on practices (65%). Those who had been in their field for longer than 10 years agreed with the statement at a higher rate than those who were in their field for less than 10 years (95% vs. 76%). This suggests the need for CAISE to continue to engage its communities with current research, and perhaps to expand its focus on disseminating current practices in ways that engage SciComm researchers.

Overall, respondents in our survey were equally likely to make use of four key strategies for staying abreast of the research literature (Table 4): reading journal articles, or reading synthesis reports, following the work of leading scholars, or attending conferences. There was an expected difference between practitioners and researchers:

While researchers' preferred strategy for keeping up with research was to read journal articles (70%), practitioners relied on this far less (25%); instead, practitioners relied more heavily (63%) on synthesis reports which researchers were far less keen to consult (25%).

ISE practitioners were more likely than SciComm practitioners (69% vs. 50%) to read reports "in order to keep up with the relevant research literature." SciComm practitioners, on the other hand, were more than twice as likely as ISE practitioners (72% to 32%) to cite conferences as one of two primary strategies for keeping up with research.

Not surprisingly, researchers cited reading journal articles as primary sources. There was a noticeable difference in the degree to which SciComm and ISE researchers follow or connect with leading SciComm or ISE researchers: 61% of SciComm researchers, versus only 38% of ISE researchers. The results from the closed-ended question were confirmed by answers to an open-ended question about resources used.

	I regularly read journals or papers	From time to time, I read reports, articles, or books that synthesize the state of research	I follow or connect with leading SciComm / ISE researchers	I attend SciComm / ISE research conferences
All respondents (n=160)	47%	44%	41%	48%
ISE (n=86)	47%	47%	40%	49%
Practitioner (n=32)	28%	69%	41%	34%
Researcher (n=39)	67%	26%	38%	31%
SciComm (n=45)	53%	33%	49%	59%
Practitioner (n=18)	22%	50%	39%	72%
Researcher (n=23)	74%	22%	61%	30%
Practitioner (n=64)	25%	63%	39%	45%
Researcher (n=67)	70%	25%	43%	46%

Table 4. What two primary strategies do you use to keep up with the relevant research literature?

A higher percentage of SciComm than ISE professionals (26% compared to 16%) cited entire bodies of work, often referencing concepts or theories that are closely associated with individuals who were mentioned in the closed-ended questions.

The results from the open-ended question also confirmed that practitioners were indeed more likely (33%) than researchers (19%) to cite "definitional" types of research resources, such as consensus studies by the National Academies or CAISE Inquiry Group papers/reports. These responses suggest an ongoing need for CAISE to identify or produce and circulate translational resources.

Connecting with practice

In parallel to the question of keeping up with research, we asked respondents how they stayed abreast of emerging or innovative approaches in SciComm or ISE (Table 5). Following or connecting with leading practitioners and attending conferences were cited almost equally (63% and 60%) and were more prominent than reading

reports and other printed materials (47%), which is not surprising as many cutting-edge practices are not yet documented in the literature.

Just as with research, however, practitioners and researchers differed in their strategies. Researchers preferred to read about new approaches (63%), followed by learning about them at conferences (54%), and lastly, by following practitioners. Practitioners preferred to follow innovative or cutting-edge colleagues the most (72%), or attend conferences for this purpose (65%), but were less likely to cite reading about new approaches (38%).

What emerges from the tables above is a distinct difference in the pattern of using peer-reviewed literature, synthesis reports, individuals and conferences as ways of staying updated with important trends in the profession. While overall researchers rely heavily on original literature, practitioners rely more on peer leaders, synthesis reports, and conferences for their professional growth. As noted above, this suggests a need for CAISE to continue to focus on making available both translational and original research.

	I regularly read reports, newsletters, & other printed matter	I follow or connect with leading science communication or informal STEM education practitioners	I attend conferences that feature emerging or innovative science communication or informal STEM education practices
All respondents (n=169)	47%	63%	60%
ISE (n=89)	48%	58%	64%
Practitioner (n=37)	43%	68%	68%
Researcher (n=35)	60%	51%	57%
SciComm (n=46)	54%	61%	54%
Practitioner (n=22)	41%	64%	68%
Researcher (n=17)	64%	59%	47%
Practitioner (n=78)	38%	72%	65%
Researcher (n=57)	63%	53%	54%

Table 5. What two primary strategies do you use to keep up with emerging or innovative approaches to either science communication or informal STEM education practices?
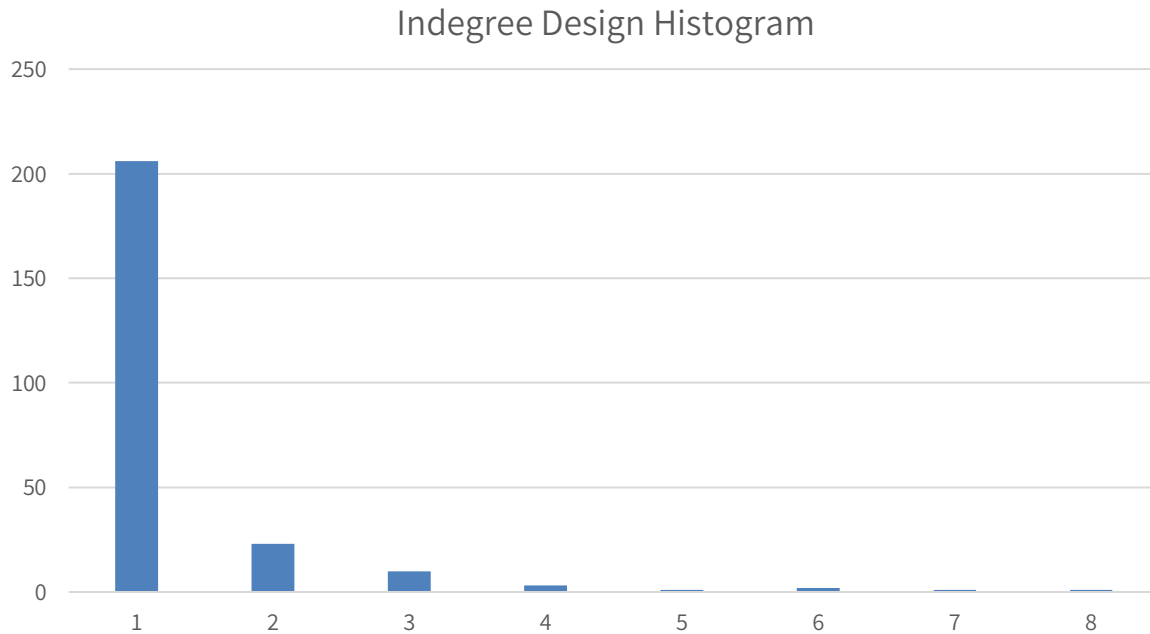
Indegree Design Histogram

Figure 12. Distribution of influencers within design and implementation. Altogether 41 individuals were named more than once. The person who was named most within this category received a total of 8 mentions (ID=8).

Who are strong influencers in design and implementation?

Figure 14 shows how few individuals could be considered key influencers in the category design and implementation (D&I), which represented an area of professional practice most commonly associated with practitioners (i.e., those who create experiences for audiences). Only 41 individuals received more than one mention as being influential. The maximum number of mentions (ID=8) was received by an ISE practitioner who was involved in a variety of national research and implementation initiatives that span into SciComm. This person was mostly mentioned by ISE respondents (practitioner and researchers), though SciComm respondents also mentioned the individual as influential in D&I. This category is not dominated by researchers, indicating that D&I, while informed by research, has strong elements of craft and wisdom from practice.

Network maps within the domain of design and implementation

Figure 15 (on the next page) exhibits the network of influencers who emerge within design and implementation. It is dominated by ISE and ISE/SciComm individuals and an unusually high number of individuals who are mentioned once or twice, but are not, through people who mention them, connected into a wider network of influencers in D&I. This may indicate a diversity of (localized) approaches within D&I, a domain dominated by practitioners with strong ties to scholarship, and scholars with strong ties to practice; however, the map might also indicate that D&I is fragmented into many more ideas and concepts than, for instance, research, and therefore appears less "coherent" and connected. The top influencers within D&I (individuals 136 and 847) are practitioners who are science museum-based but lead or have led national projects with a strong SciComm element.
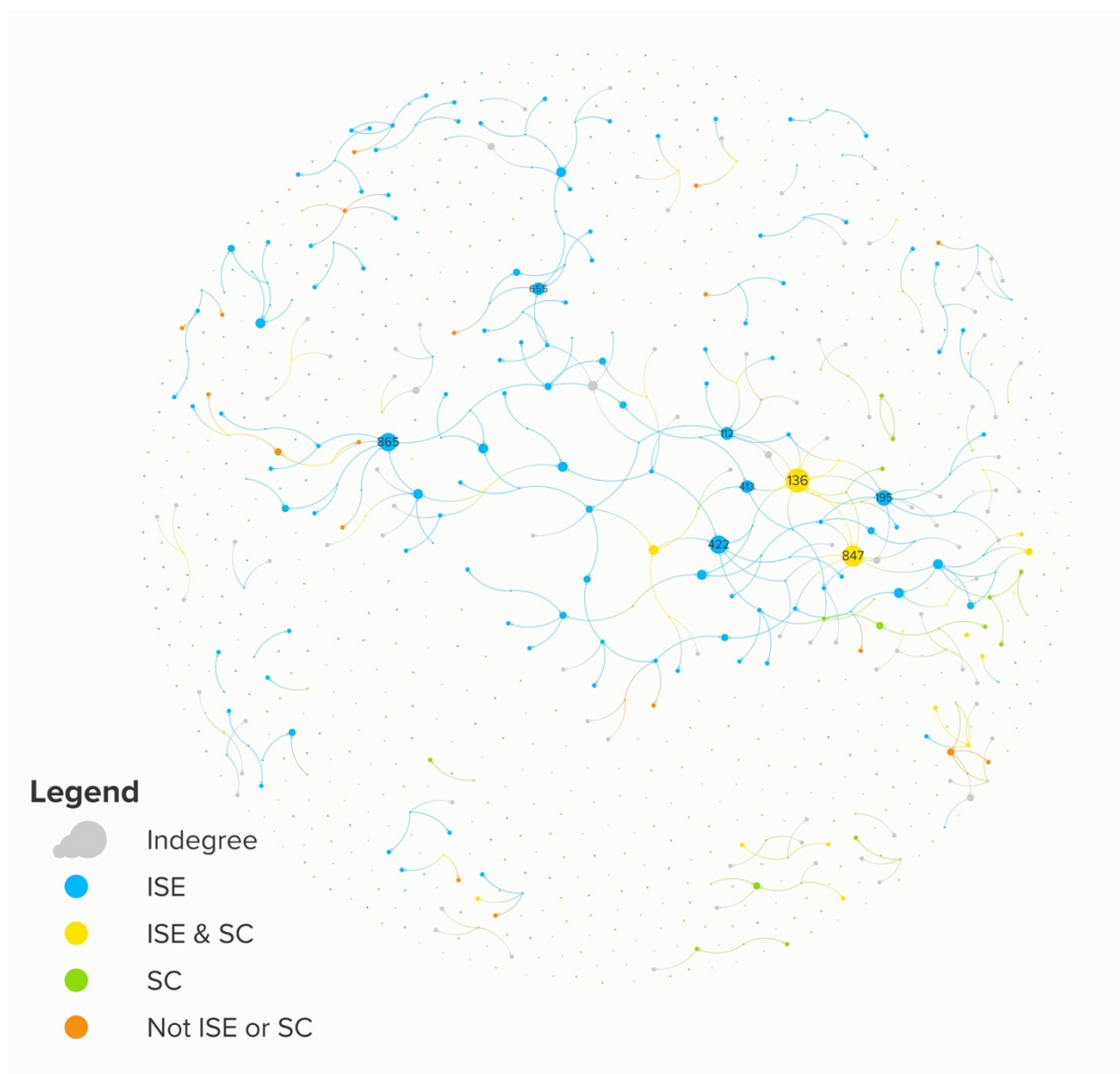
Figure 13. Network of all individuals mentioned as influential by respondents to the survey, within the domain of design and implementation, by sector. The size of the dot represents indegree (number of mentions); arrows indicate direction of mention. SC = SciComm.

Who are key influencers in evaluation and measurement?

Figure 16 (on the next page) shows the histogram of all those mentioned at least once in the category of evaluation and measurement. Fifty-five individuals received more than one mention as being influential. Two individuals had the maximum

number of mentions (ID=9). One of them was an ISE researcher and evaluator identified exclusively by ISE respondents, but was equally mentioned by researchers and practitioners.

The other most frequently mentioned person in this category, mentioned mostly by ISE practitioners, works as an in-house evaluator and researcher at a major science museum.

Indegree Evaluation Histogram
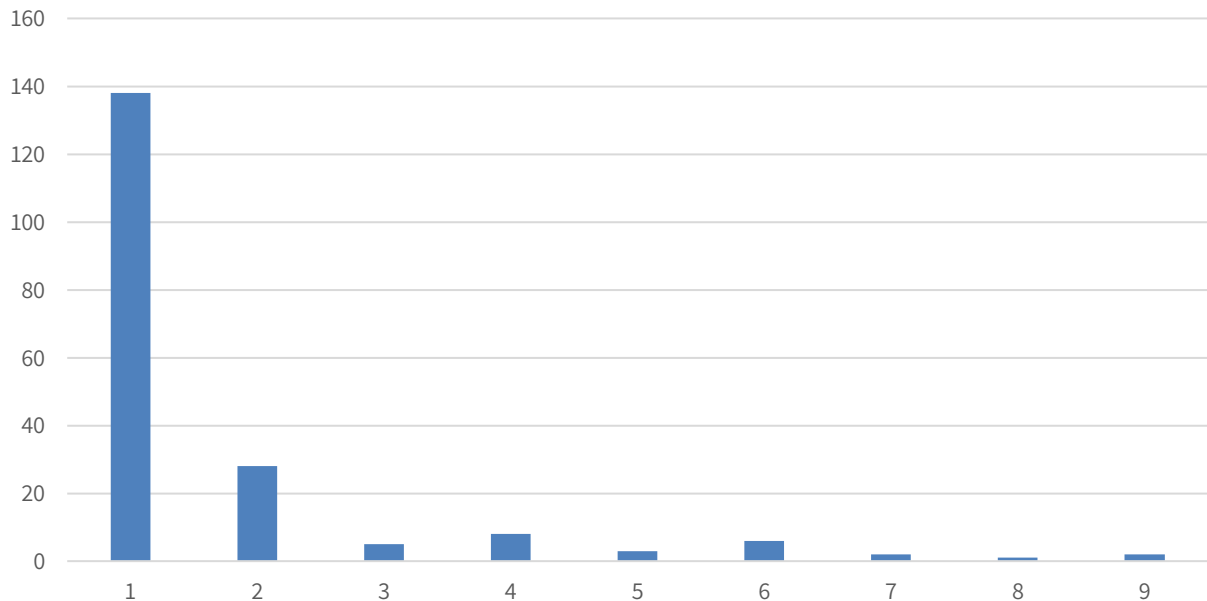
Figure 14. Distribution of influencers within evaluation and measurement. Altogether, 55 individuals were named more than once. Two people received the most mentions in this category, at nine mentions each (ID=12).

In fact, 18 of the top 20 names on the list of influencers are individuals who have done considerable work in ISE evaluation and are or have been active in, or associated with, the Visitor Studies Association (VSA), a membership organization dedicated to understanding and enhancing learning experiences in informal settings through research, evaluation, and dialogue. One individual is a SciComm researcher who is now beginning to evaluate SciComm activities.

Even controlling for the fact that almost twice as many survey respondents identified as ISE rather than SciComm, the data still suggest that the practice of evaluation and measurement is stronger in ISE than in SciComm. This has been corroborated at the Sackler Colloquium on the Science of Science Communication conferences and the Evolving Culture of Science Engagement meeting in 2013 (Linett et al., 2014).

Network maps within the domain of evaluation and measurement

Figure 17 shows the network of influencers who emerge within Evaluation and Measurement. ISE professionals or those who identify as both ISE and SciComm, with a small number of SciComm individuals included, lead this domain. The map also shows a considerable number of individuals at the periphery of the network, suggesting many small and local support structures.

Note that individuals at the periphery of these open networks are not necessarily isolated; rather, only one individual mentions them or a few people mention them who themselves were not named.

Figure 18 (on the next page) shows the 3-degree ego-network for the person most named in evaluation and measurement (individual 971). The map includes the second- (808) and third-most named individual (71) as well. Note that within three degrees of naming, no SciComm person can be found, suggesting that the evaluation and measurement communities of ISE and SciComm are likely very distinct, with little connection, at least within our sample of 231 survey respondents.
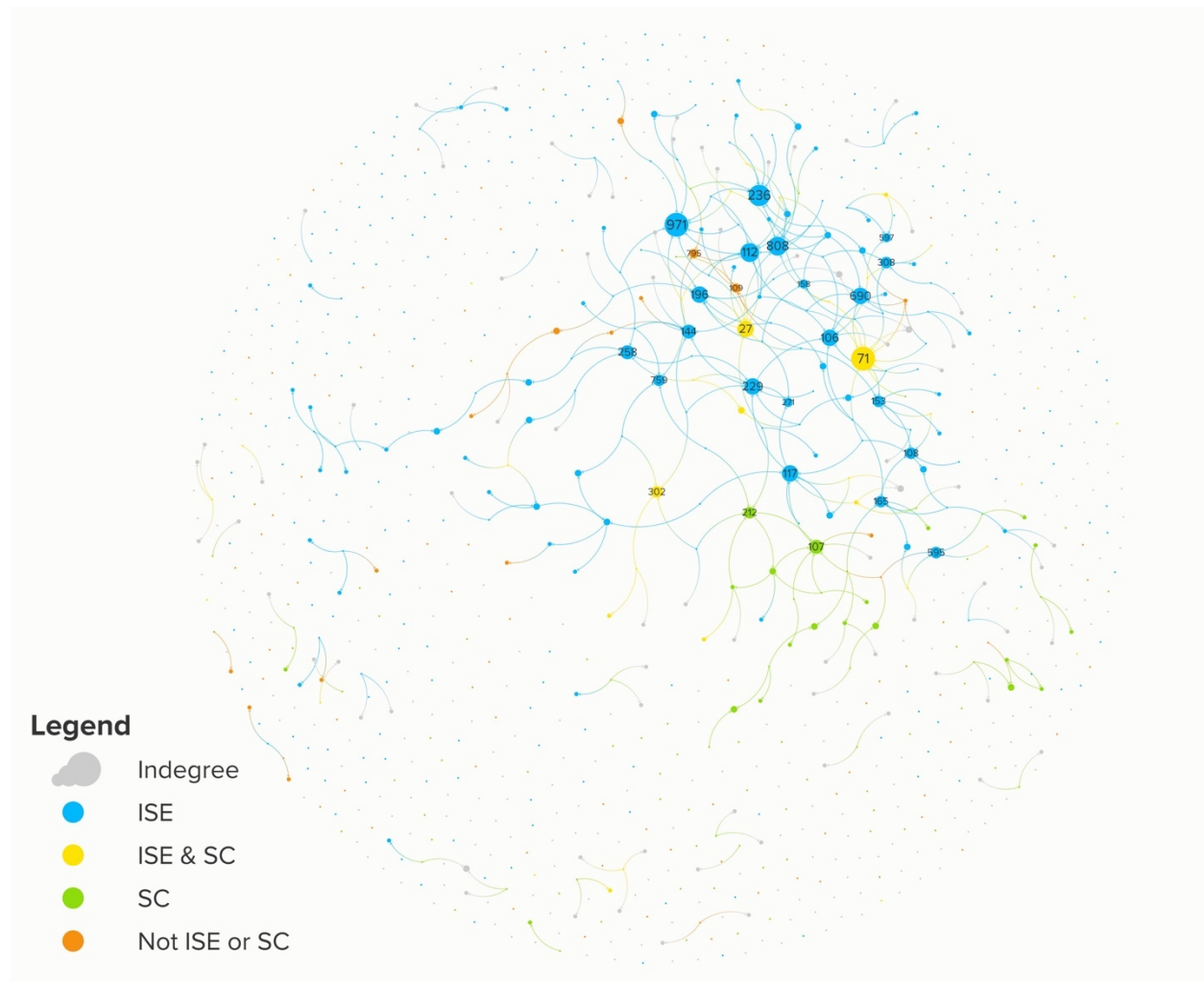

Figure 15. Network of all individuals mentioned as influential by respondents to the survey, within the domain of evaluation and measurement, by sector. The size of the dot represents indegree (number of mentions); arrows indicate direction of mention. SC = SciComm.
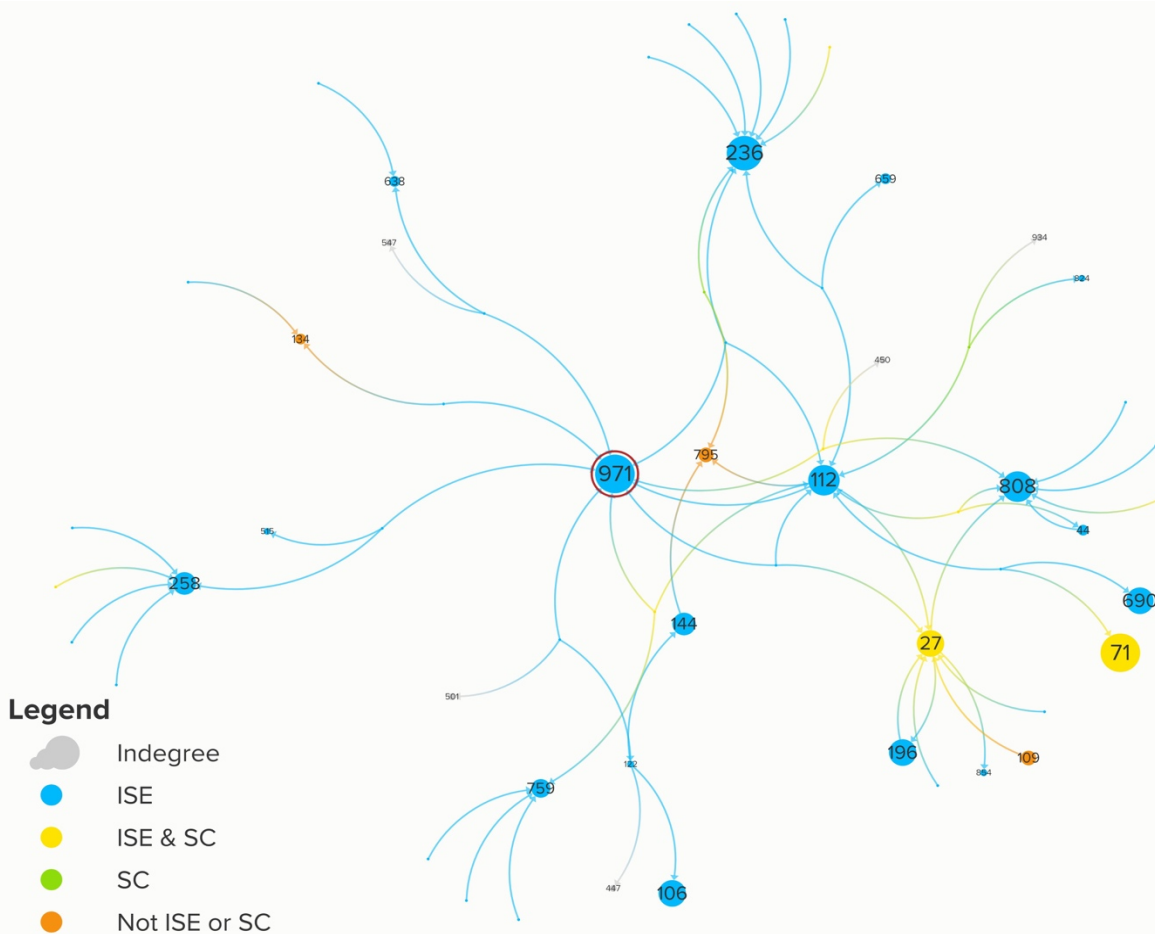
Figure 16. 3-degree network of the individual most mentioned as influential by respondents to the survey within the domain of evaluation and measurement, by sector (971). The size of the dot represents indegree (number of mentions); arrows indicate direction of mention. SC = SciComm.

Resources in evaluation and measurement

Altogether 154 respondents indicated that their work involved evaluation and measurement (see Table 6, next page). Those who identified as SciComm were less likely to indicate this than ISE professionals (74% vs. 89%), and practitioners were less likely than researchers to do so (77% vs. 87%). Almost three-quarters of respondents (73%) were using custom-designed instruments in their work. In fact, researchers were more likely to do so than practitioners. Existing or validated instruments were mentioned less frequently as a strategy (36%);

not surprisingly, researchers were more likely to use them than practitioners (40% vs. 29%).

Surprisingly, ISE professionals who answered the open-ended questions about resources were far more likely (68%) to use off-the-shelf instruments than their SciComm peers (42%). Two-thirds of practitioners, but only roughly a third of researchers were partnering with external evaluators, which might be expected. Further, just 29% of practitioners and 18% of researchers were partnering with (other) researchers, a result that suggests that (university) researchers play a far smaller role in evaluation and measurement than external evaluators.

	Using existing, validated instruments or protocols	Using custom designed instruments or protocols	Partnering with external evaluators	Partnering with external researchers
All respondents (n=154)	36%	73%	51%	25%
ISE (n=89)	36%	71%	54%	26%
Practitioner (n=32)	38%	63%	69%	34%
Researcher (n=38)	42%	76%	37%	18%
SciComm (n=46)	33%	65%	33%	15%
Practitioner (n=16)	19%	56%	56%	21%
Researcher (n=20)	40%	85%	25%	19%
Practitioner (n=62)	29%	61%	65%	29%
Researcher (n=62)	40%	79%	37%	18%

Table 6. Which of the following four strategies do you or your programs/efforts most commonly use for measurement and evaluation?

Familiarity with and use of CAISE resources

Respondents were asked about their familiarity with CAISE, their use of the website InformalScience.org, and their participation in CAISE events. Overall, 85% of respondents were familiar with CAISE, though there was a difference between ISE and SciComm: 99% of those who clearly identified as ISE and 91% of those who identified as both, SciComm and ISE, were familiar, but "only" 58% of the SciComm respondents were familiar with CAISE.

There was no difference between researchers and practitioners in their answers to the question.

Half of the respondents stated that they were visiting the CAISE website InformalScience.org several times a year, and 14% did so at least monthly (Table 7). ISE respondents were far more likely to use the website than SciComm respondents, a third of whom were not familiar with the website. Researchers were somewhat more likely to use the website on a regular basis than practitioners, but also more likely to not be familiar with the site.

	Frequently (at least once a month)	Occasionally (several times a year)	Rarely	Never	I have not heard of this website
All respondents (n=185)	14%	49%	19%	6%	11%
ISE (n=94)	21%	62%	15%	1%	1%
SciComm (n=56)	0%	25%	30%	11%	34%
Practitioner (n=80)	11%	51%	24%	6%	8%
Researcher (n=71)	17%	45%	15%	6%	17%

Table 7. How often do you visit InformalScience.org?

A somewhat similar pattern emerged in terms of attending CAISE events (Table 8). The vast majority (84%) of ISE respondents had attended at least one, and 43% stated that they had attended at least four events. In contrast, only 31% of SciComm respondents had ever attended a CAISE event, and only 9% had done so four or more times.

These data strongly suggest that CAISE has considerable growth potential for reaching new audiences amongst science communication scholars and practitioners. In fact, the use of a repeat survey with the respondents to this survey around familiarity and use of CAISE resources could be a summative indicator on the impact of CAISE within the communities it serves.

	0	1	2	3	4 or more
All respondents (n=184)	34%	13%	14%	10%	29%
ISE (n=94)	16%	16%	15%	11%	43%
SciComm (n=55)	69%	5%	11%	5%	9%
Practitioner (n=80)	35%	14%	11%	13%	28%
Researcher (n=70)	36%	14%	16%	3%	31%

Table 8. How many CAISE events have you attended?

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Appendix A: Additional Table

	Ranking	Overall Namings	ISE Namings	SciComm Namings	Researcher Namings	Practitioner Namings
General	1st choice	218	113	58	84	94
	2nd choice	206	107	55	80	90
	3rd choice	195	103	50	76	84
	Total	**619 (89%[1])**	**323 (52%[2])**	**163 (26%[2])**	**240 (39%[2])**	**268 (43%[2])**
Broadening Participation	1st choice	145	85	31	58	58
	2nd choice	127	77	26	50	51
	3rd choice	95	62	15	39	35
	Total	**367 (53%[1])**	**224 (61%[2])**	**72 (20%[2])**	**147 (40%[2])**	**144 (39%[2])**
Research and Scholarship	1st choice	162	90	45	69	63
	2nd choice	148	85	38	62	58
	3rd choice	120	65	33	55	44
	Total	**430 (62%[1])**	**240 (56%[2])**	**116 (27%[2])**	**186 (43%[2])**	**165 (38%[2])**
Design and Implementation	1st choice	142	82	34	50	66
	2nd choice	111	68	21	40	49
	3rd choice	76	49	11	25	39
	Total	**329 (47%[1])**	**199 (60%[2])**	**66 (20%[2])**	**115 (35%[2])**	**154 (47%[2])**
Measurement and Evaluation	1st choice	145	82	34	56	64
	2nd choice	116	68	24	46	49
	3rd choice	80	47	13	34	33
	Total	**341 (49%[1])**	**197 (58%[2])**	**71 (21%[2])**	**136 (40%[2])**	**146 (43%[2])**
TOTAL		**2086**	**1183 (57%[2])**	**488 (23%[2])**	**824 (40%[2])**	**877 (42%[2])**

Table: Distribution of namings by sector and role identity of the names across all five naming categories. The categories are listed in the order in which they occurred on the survey. The data show the degree to which names were generated vis-à-vis the total namings possible, by naming position. The percentages represent the proportion of namings as a percentage of the total possible.

[1]Percentage of total namings possible. In the general category, 69% of the total possible names (had anyone given three) were generated.

[2]Percentage contribution to the total namings by each of the sector and roles. Note that those identified as Both or Neither are not included.

Across all categories, 57% of the namings were provided by ISE professionals.

Appendix B: Survey Questionnaire

Science Communication and Informal STEM Education: A Social Network Analysis

Thank you for agreeing to share your perspective in this survey. The Center for Advancement of Informal Science Education (CAISE) is exploring how the fields of science communication and informal STEM education relate to and learn from one another. We are trying to understand how people are connected and what ideas about public engagement with science are most influential in the respective fields. We are aware that there is debate about who and what is included in "science communication" and "informal STEM education," that there are no canonical definitions, and that some see considerable overlap between the two. Rather than define these terms and communities from our perspective, we encourage you to use your own understanding as you answer the questions.

Your responses will be treated with complete confidentiality. As a token of our appreciation for your time, we can send you a visualization of the social network this survey produces and highlight your location within the map. The map will not contain any names, but will label types of institutions, locations, and communities, revealing connections within and across communities, and the kinds of ideas and strategies being used in different sub-communities. Furthermore, we will email you aggregated and anonymized results before we share them publicly later this year.

Section 1. Background

We'd like to ask you a few questions about your background. This information will be kept entirely confidential.

1. How many years have you been working in science communication or informal STEM education?
   Fewer than five years (1) ... More than 10 years (3)

2. How long have you been in your current position?
   Fewer than five years (1) ... More than 10 years (3)

3. Your organization

4. Your title

5. Please briefly describe your role in your organization.

6. Zip code where you are located

Section 2. People in Your Field

To give us an idea of the scope of your field, please answer a few questions about whose work you turn to (in print, in person, or in other forms) to inform your own work.

7. Whose work has had the greatest influence on your thinking and professional practice in science communication or informal STEM education? Please list up to three people who have had the greatest influence on your work.
    Influential person 1 _____
    Influential person 2 _____
    Influential person 3 _____

CAISE is particularly interested in three areas of challenge that span informal STEM education and science communication: Expanding efforts to broaden participation in STEM and STEM education (increasing diversity of those who pursue STEM, and who are participants in science communication and informal STEM education work). Strengthening connections between research and practice (specifically *research* in the learning sciences and social sciences and *practices* of informal STEM education or science communication). Measuring and evaluating the impacts and outcomes of informal STEM education and science communication.

If any of the questions is not relevant to your work, please leave it blank.

8. Whose work in broadening participation has had the greatest influence on your thinking and professional practice? Please list up to three people. Leave blank if not relevant for your work.
    Influential person 1 _____
    Influential person 2 _____
    Influential person 3 _____

9. Whose research and scholarship has had the greatest influence on your thinking and professional practice? Please list up to three people. Leave blank if not relevant for your work.
    Influential person 1 _____
    Influential person 2 _____
    Influential person 3 _____

10. Whose work has had the greatest influence on your thinking and professional practice with respect to program design and implementation? Please list up to three people. Leave blank if not relevant for your work.
    Influential person 1 _____
    Influential person 2 _____
    Influential person 3 _____

11. Whose work in outcomes/impacts measurement and evaluation has had the greatest influence on your thinking and professional practice? Please list up to three people. Leave blank if not relevant for your work.
    Influential person 1 _____
    Influential person 2 _____
    Influential person 3 _____

12. We understand that your work may cross over multiple fields. Nevertheless, please let us know where you stand, most of the time, with respect to the following two aspects of your work. Please indicate where on a continuum of science communication and informal STEM education you primarily identify:
    o Informal STEM education
    o Both, but more with informal STEM education than with science communication
    o Both equally
    o Both, but more with science communication than with informal STEM education
    o Science communication
    o I don't identify professionally with either of these fields. Please explain: _____

13. Please indicate where on a continuum of informal STEM education/science communication researcher or practitioner you primarily identify:
    o Practitioner
    o Both, but more as a practitioner than as a researcher
    o Equally as a practitioner and researcher
    o Both, but more as a researcher than as a practitioner
    o Researcher
    o I don't identify professionally as either a practitioner or a researcher in informal STEM education or science communication. Please explain: _____

Section 3. Goals and Strategies

Please make selections in this section to help us understand the goals and strategies you employ in different areas of your work.

14. Is your work intentionally focused on broadening participation in the STEM fields or in the areas of science communication or informal STEM education?
    o Yes
    o No

15. Which two primary approaches or strategies do you use for broadening participation?
    o Addressing barriers to access (such as location, cost, timing, frequency)
    o Changing participant recruitment and retention strategies
    o Co-designing programs/activities with underrepresented audiences
    o Building partnerships with organizations and programs that serve underrepresented audiences
    o Changing hiring and staffing practices
    o Changing programming to appeal to underrepresented audiences
    o Other: _____

16. Please name or describe the one resource (e.g., a research study, program, model, facilitation strategy, or professional development resource) that has been most useful or informative for your efforts in broadening participation in science communication or informal STEM education efforts.
    How did you first become aware of the resource? If possible, please share the name of the source (e.g. journal, conference, colleague, etc.) _____

Please provide as much information as you can about this resource (e.g., name, author, institution, publication) so that we can try to locate it ourselves. _____

17. Does your work include measuring or evaluating the impacts/outcomes of informal STEM education or science communication efforts, whether it is your own work or the work of others? This could include hiring, arranging, partnering, responding to, or leading measurement and evaluation.
    o   Yes
    o   No

18. Which of the following four strategies do you or your programs/efforts most commonly use for measurement and evaluation?
    o   Using existing, validated instruments or protocols
    o   Using custom designed instruments or protocols
    o   Partnering with external evaluators
    o   Partnering with external researchers

19. If you can, please name or describe a specific measurement instrument or assessment tool that has been most useful to your work. Please provide as much information as you can about this tool so we can locate it ourselves.
    What did the instrument measure? _____
    If you can, please let us know where you found this resource, or who created it: _____

20. Do you try to keep up with the research literature in science communication or informal STEM education?
    o   Yes
    o   No

21. What two primary strategies do you use to keep up with the relevant research literature?
    o   I regularly read journals or papers
    o   From time to time, I read reports, articles, or books that synthesize the state of research
    o   I follow or connect with leading science communication/ISE researchers
    o   I attend science communication/ISE research conferences
    o   Other: _____

22. Please share or describe a research study or finding that has been most significant for your work or that has most influenced your thinking. Please provide as much information as you can about this study or finding so we can locate it ourselves. Please provide as much reference information here as possible (title, author(s), year, journal, etc.: _____

23. Do you try to keep up with emerging or innovative approaches to either science communication or informal STEM education practices? By "approaches" we mean the design and implementation of science communication or informal STEM education programs, experiences, settings, or materials.
    o   Yes
    o   No

24. What two primary strategies do you use to keep up with emerging or innovative approaches to either science communication or informal STEM education practices?

> I regularly read reports, newsletters, and other printed matter
> I follow or connect with leading science communication or informal STEM education practitioners
> I attend conferences that feature emerging or innovative science communication or informal STEM education practices
> Other: _____

25. If relevant to your work, please share a specific approach that has served as an inspiration or model for your own work. Please provide as much information as you can about this approach so we can locate it ourselves.

> Approach (model, program, design): _____
> Where did you learn about this approach? _____
> Who created this approach (name, organization)? _____

26. Are you familiar with the Center for Advancement for Informal Science Education (CAISE)?
    - ○ Yes
    - ○ No

27. How often do you visit InformalScience.org?
    - ○ Frequently (at least once a month)
    - ○ Occasionally (several times a year)
    - ○ Rarely
    - ○ Never
    - ○ I have not heard of this website

28. How many CAISE events have you attended (including AISL PI meetings since 2008, CAISE Inquiry Groups, and/or other CAISE convenings, such as ones on broader impacts and informal STEM education, media, professional development, organizational networks, approaches to professional development, research agendas, or evaluation capacity-building)?
    - ○ 0
    - ○ 1
    - ○ 2
    - ○ 3
    - ○ 4 or more

29. Is there anything else you would like to tell us about your engagement with CAISE?

30. Could you suggest other leaders in the fields of either science communication or informal STEM education to whom we should send this survey? Please list their names and email addresses.

31. Would you like to receive the results of this survey, in the form of a data visualization map?
    - ○ Yes
    - ○ No thanks