

# Scialog 2012

## Social Network Survey of Interconnectedness Impact

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## Executive Summary

An important goal of Research Corporation for Science Advancement (RCSA) is to accelerate transformative research. An important goal of the Scialog conferences is to facilitate interdisciplinary team building, encourage the exchange of ideas, and build future collaborations that result in tangible research outcomes. To measure and eventually enable informed improvement of the Scialog conference process, we performed a network-based study to not only establish *whether* the Scialog conferences accomplish these goals, but *how and why* they accomplish these goals.

To this end, we gave a survey to Scialog participants to measure their research relationships with other Scialog participants before and after the conference. The participants were asked to identify outcomes from previous Scialog relationships and to categorize their relationships before and after the 2012 conference into *Unfamiliar*, *Aware*, *Discussion*, or *Collaboration* (see report for descriptions of each category) to reflect a simple model of the steps required to actually reach a point where two participants can collaborate. This report is the third report in the series of analyses to measure the tangible research outcomes from Scialog.

As with the 2011 report, this report addresses the long-term impact of the Scialog conference by measuring the persistence of relationships and investigating tangible research outcomes from relationships forged at Scialog.

### Key insights

- Out of 54 active solar energy researchers, the Scialog conference resulted in an average of 14.8 new awareness connections, 10.4 new discussion connections, and 1.7 new collaboration connections to other researchers, quite similar to results from last year's conference with a slight increase in discussion and collaboration connections.
- We confirm last year's result that traditional conference activities (formal presentations, poster sessions, undirected dialog, and breakout sessions) tend to lead to awareness and discussion among participants whereas writing joint proposals is a strong incentive for Scialog participants to collaborate.
- The majority (58%) of links created during mini-breakout sessions created new collaboration ties between previously unfamiliar people, suggesting that the mini-breakout sessions may have been a key driver in fostering collaboration.
- In contrast to 2010 and 2011, connections (of any type: Awareness, Discussion, and Collaboration) made during the Scialog conference are not more interdisciplinary than the pre-conference connections.
- About 75% of the most innovative ideas tend to be shared during undirected dialogs (~35%), formal presentations (25%), and breakout sessions (15%). This is different from 2011 where the most innovative ideas were during formal presentations (52%) and undirected dialogs (23%).
- We confirm 2011's result that over 45% of new collaboration connections were made between individuals that thought each other's ideas were very innovative.

- Nearly every active solar energy researcher shared a referral with one of their colleagues and undirected dialog fosters the most referrals.
- Although the pre- and post- conference networks have visually apparent silos of connectivity between the classes of 2010, 2011 and 2012, the links that are added during the conference do not appear biased. Indeed, the links that are formed between all pairs of classes are evenly distributed, indicating that the class of 2012 integrated smoothly into the Scialog community.
- Data from three conferences indicate that Scialog has a substantial effect in creating collaborative links and that tangible research outcomes tend to come only from linked individuals that leave the conference as collaborators.

### **Follow-up items and promising future directions**

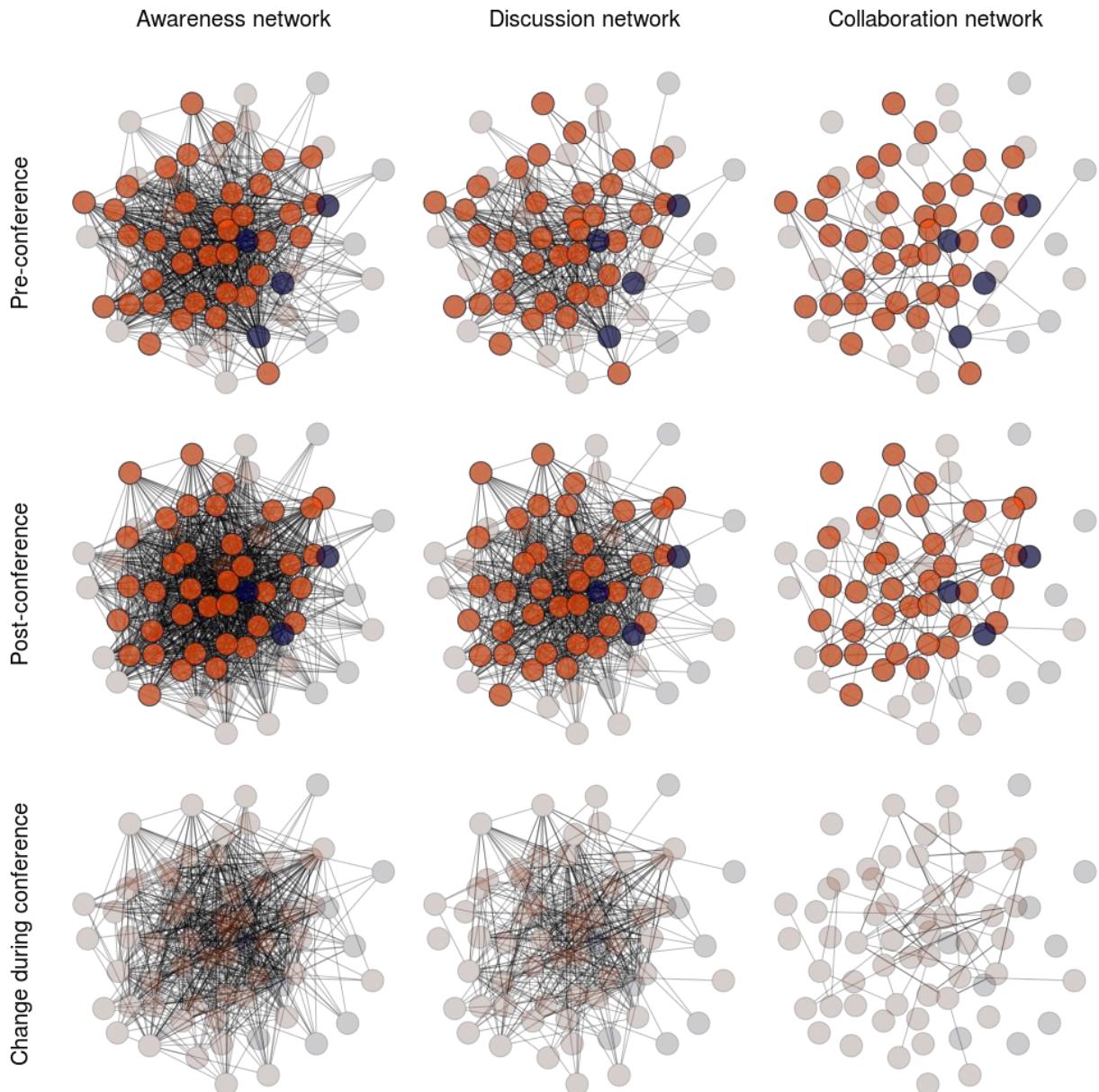
- Given enough time, will discussions and referrals that were initiated at Scialog turn into collaborations with tangible research outputs?
- Will collaborations forged at Scialog result in more impactful research than other collaborations forged by the Scialog awardees?
- Comparison of these results with other conferences, such as Gordon Conferences, would provide a way to assess how the unique aspects of Scialog (such as the joint proposal writing) encourage the transition to new collaborations.

## **Building interdisciplinary teams during Scialog**

### **Network growth**

We surveyed the relationships between Scialog participants before and after the conference. Specifically, we asked individuals to classify their relationship as either being aware of someone else's work (*aware*), having detailed discussions with another individual (*discussion*), or collaborating with another individual (*collaboration*). These relationship types were chosen as they are nearly perfect subsets of one another; it is not possible to have detailed discussions with another individual without being aware of their work and it is not possible to collaborate with another individual without having detailed discussions and being aware of that person's work.

By asking the same question before and after the survey, we are able to quantify the extent to which Scialog facilitated the growth of these participants' professional networks (Fig. 1), particularly the active solar researchers. We find that, on average, each researcher became aware of the work of an additional 14.8 researchers, each researcher had detailed discussions with an additional 10.4 researchers, and that each researcher participated in an additional 1.7 collaborations as a result of Scialog. Interestingly, these patterns are strikingly similar to those from the 2010 and 2011 conferences.

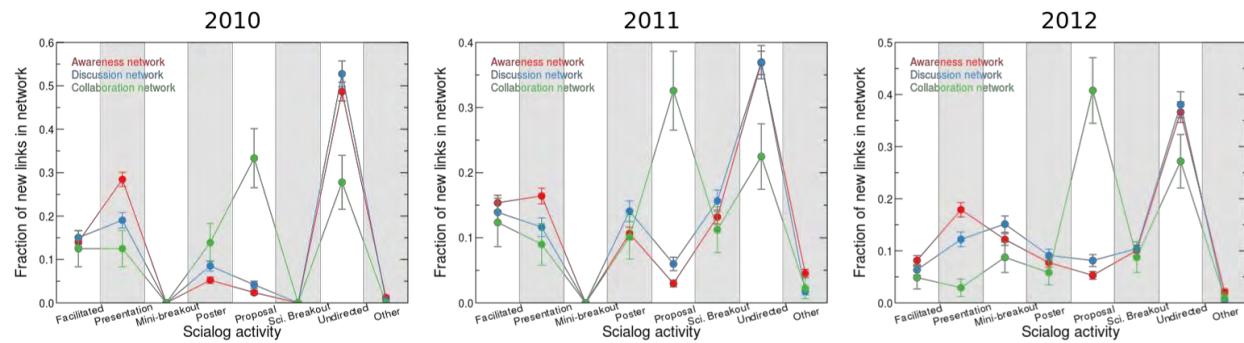


**Figure 1. Dramatic changes in relationships during Scialog.** These nine diagrams show the pattern and types of relationships between Scialog participants before Scialog (*Pre-conference*), after Scialog (*Post-conference*), and how those relationships changed during Scialog (*Change during conference*). Circles represent Scialog participants, and links between circles appear when at least one of the linked participants indicated in the survey that they are aware of the other's research (*Awareness network*), have had detailed research discussions with him or her (*Discussion network*), or have collaborated with him or her (*Collaboration network*). Circles are positioned using a [force-directed placement algorithm](#). Orange circles represent participants that are active solar researchers and blue circles represent participants that are not active solar researchers. A faded circle indicates that the participant did not finish the survey. All circles are faded in the *Change during conference* networks so that the new links are prominently visible. This diagram serves as a “birds-eye” view of the network changes, and details of the changes in the relationship types will be discussed in more detail later, but there are two notable aspects that jump out immediately: (i) Scialog facilitated an average of 14.8 new awareness connections among researchers, 10.4 new discussion connections among researchers and 1.7 new collaboration connections among researchers, and (ii) these changes in network connectivity during the 2011 Scialog conference are quite similar to the changes in connectivity during the 2010 Scialog conference (12.7 / 11.4 / 1.2) and 2011 Scialog conference (16.5 / 8.5 / 1.0). To put this in context,

there were a total of 40 / 47 / 54 active solar researchers at the Scialog conferences in 2010 / 2011 / 2012 respectively.

### Scialog activities impacting network growth

The mere existence of new links is to be expected at any meeting of unfamiliar individuals. The more pertinent question for any conference organizer is “*how and why* are these links formed?” To address these questions, we asked Scialog participants to also provide some context for any change in relationship by indicating whether facilitated discussions (*facilitated*), formal presentations (*presentation*), mini-breakout sessions (*mini-breakout*), poster session (*poster*), writing a proposal for supplemental funding (*proposal*), scientific breakout sessions (*sci. Breakout*), undirected dialog (*undirected*), or other activities (*other*) facilitated these new relationships. Importantly, we allowed Scialog participants to mark more than one activity for each relationship change to acknowledge the fact that several different aspects of the Scialog conference may have played a role in the change.

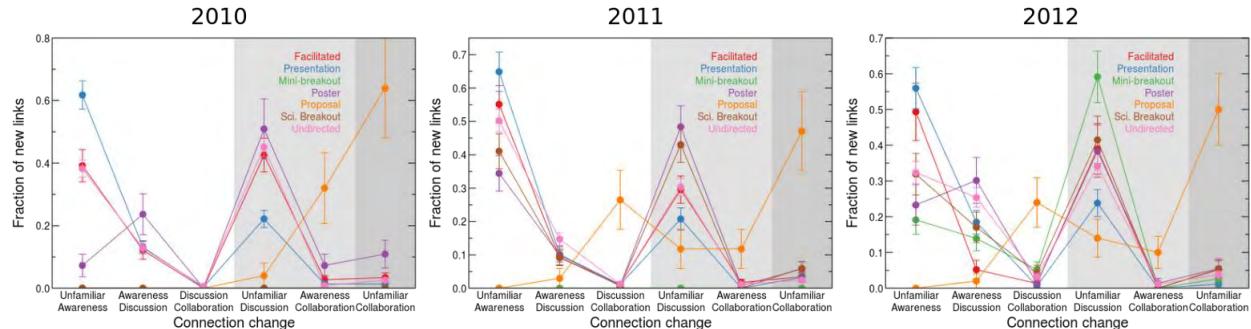


**Figure 2. Scialog activities facilitated the formation of new relationships.** Given that a new relationship of a particular type (*Awareness*, *Discussion*, or *Collaboration*) is formed during Scialog, we quantify the activities that directly facilitated the change in relationship. Error bars are computed based on a [multinomial model](#). As with previous years, undirected dialog plays an important role in every type of new relationship, particularly in forming new *Awareness* and *Discussion* links where undirected dialog still contributes to over 35% of new links. New *Collaboration* links, on the other hand, are influenced by both proposal activities and undirected dialogs. The newly introduced mini-breakout sessions in Scialog 2012 contributed roughly the same as the breakout sessions for all three link types. The pattern overall is strikingly constant between years.

We quantify the impact of Scialog activities in two ways. First, we quantify the extent to which each Scialog activity influenced the formation of new relationships (Fig. 2). This analysis reveals that undirected dialog plays a very important role in forming new relationships, regardless of the type of relationship. It also clearly demonstrates that preparing proposals for supplemental funding played an important role in forming new collaborations. Amazingly, the patterns observed in 2012 are strikingly similar to the patterns observed in 2010-2011 despite the fact that the mini-breakout sessions were introduced this year.

Second, we quantify the magnitude of the effects of these different activities on relationship changes during the Scialog conference (Fig. 3). Interestingly, nearly all of the activities have similar patterns of impact on relationship changes with the exception that writing a proposal has the most transformative impact on relationships, oftentimes resulting in collaborations between otherwise unfamiliar individuals. This result clearly demonstrates that, unlike traditional

conference activities, proposal activities provide a strong incentive for participants to become collaborators at the Scialog conference.



**Figure 3. Each Scialog activity encouraged specific types of new relationships.** Given that a new link was formed during a particular Scialog activity, we quantify the nature of the change in relationship. Error bars are computed based on a [multinomial model](#). Background shading denotes the magnitude of the relationship change; white shading represents a modest change in the relationship, light grey shading represents a substantial change in the relationship, and dark grey shading represents a transformative change in the relationship. Similar to 2011, all conference activities except proposal have the same pattern of impacting relationships; these activities tend to change relationships from *Unaware* to either *Aware* or *Discussion* and the mini-breakout sessions appear to fit the same role as the breakout sessions. As with both 2010 and 2011, proposals forge *Collaborations* among individuals that may or may not have had any relationship beforehand.

An interesting feature of the 2012 conference compared with previous years' conferences was the introduction of mini-breakout sessions. Interestingly, the majority (58%) of links created during mini-breakout sessions created new collaboration ties between previously unfamiliar people, suggesting that the mini-breakout sessions may have been a key driver in fostering collaboration.

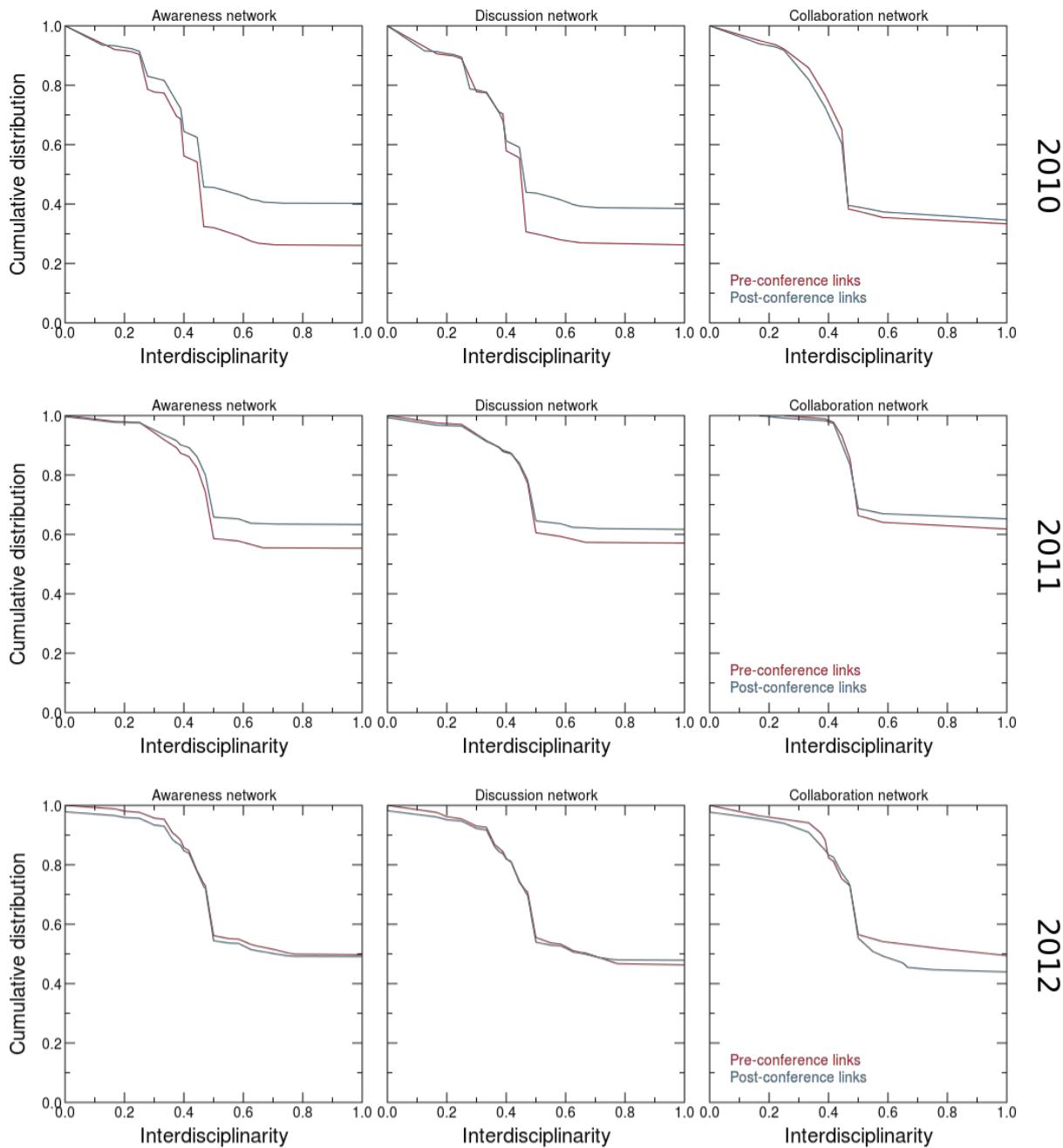
As these results emphasize, each Scialog activity had a different effect on the formation of new relationships and strengthening of existing relationships. It will be interesting to see how these new relationships mature now that the Scialog conference has concluded. Will collaborations fostered by writing proposals flounder without funding? Will awareness connections flourish in subsequent Scialog conferences? Addressing these questions are of utmost importance for informing RCSA's strategy in funding research and conducting scientific meetings.

### The interdisciplinarity of new connections during Scialog

Another important aspect of network building during the Scialog conference is the extent to which the new connections are interdisciplinary. We therefore asked Scialog participants to self-identify their field as one or more of administration, applied mathematics, biochemistry, biophysics, chemistry (analytical, inorganic, organic, physical), engineering (chemical, electrical, materials, mechanical), materials science, physics (atomic and molecular, condensed matter, optics), or other.

This information enables us to assess the interdisciplinarity of awareness, discussion, and collaboration connections before and after the Scialog conference (Fig. 4). Unlike in past years when the awareness and discussion connections made during the conference are visually more

interdisciplinary than the connections that existed before the conference, this pattern does not exist in the 2012 Scialog conference. Although it is true that the interdisciplinarity of the preconference Awareness and Discussion networks was relatively high, the interdisciplinarity was actually higher in 2011 which still produced more interdisciplinary connections in the post-conference Awareness and Discussion networks. It is unclear what caused this break from previous years but it is something to consider in future iterations of the Scialog conference.



**Figure 4. Relationship after Scialog 2012 are not more interdisciplinary, in contrast to 2010 and 2011.** The cumulative distribution of the interdisciplinarity of connections between individuals in the pre-conference (red) and post-conference network (blue) for each relationship type (Awareness, Discussion, and Collaboration). In both 2010

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and 2011 analysis that the pre- and post-conference interdisciplinarity distributions are visually distinct in the Awareness and Discussion networks but virtually the same in the Collaboration network, and Awareness and Discussion links made during the Scialog conference were significantly more interdisciplinary than the pre-conference links whereas links made during the Scialog conference were not significantly more interdisciplinary than pre-conference links. In 2012, pre- and post-conference interdisciplinarity distributions are not significantly different regardless of relationship type (Awareness, Discussion, Collaboration).

We assess whether the connections formed during the Scialog conference were more interdisciplinary than connections that existed before the conference using [bootstrap hypothesis testing](#). We confirm our visual suspicions; we can reject the hypothesis that the awareness ( $P = 0.241$ ), discussion ( $P = 0.923$ ), and collaboration ( $P = 0.460$ ) connections made during the conference are more interdisciplinary than pre-conference connections. This finding suggests that something changed during this years' conference.

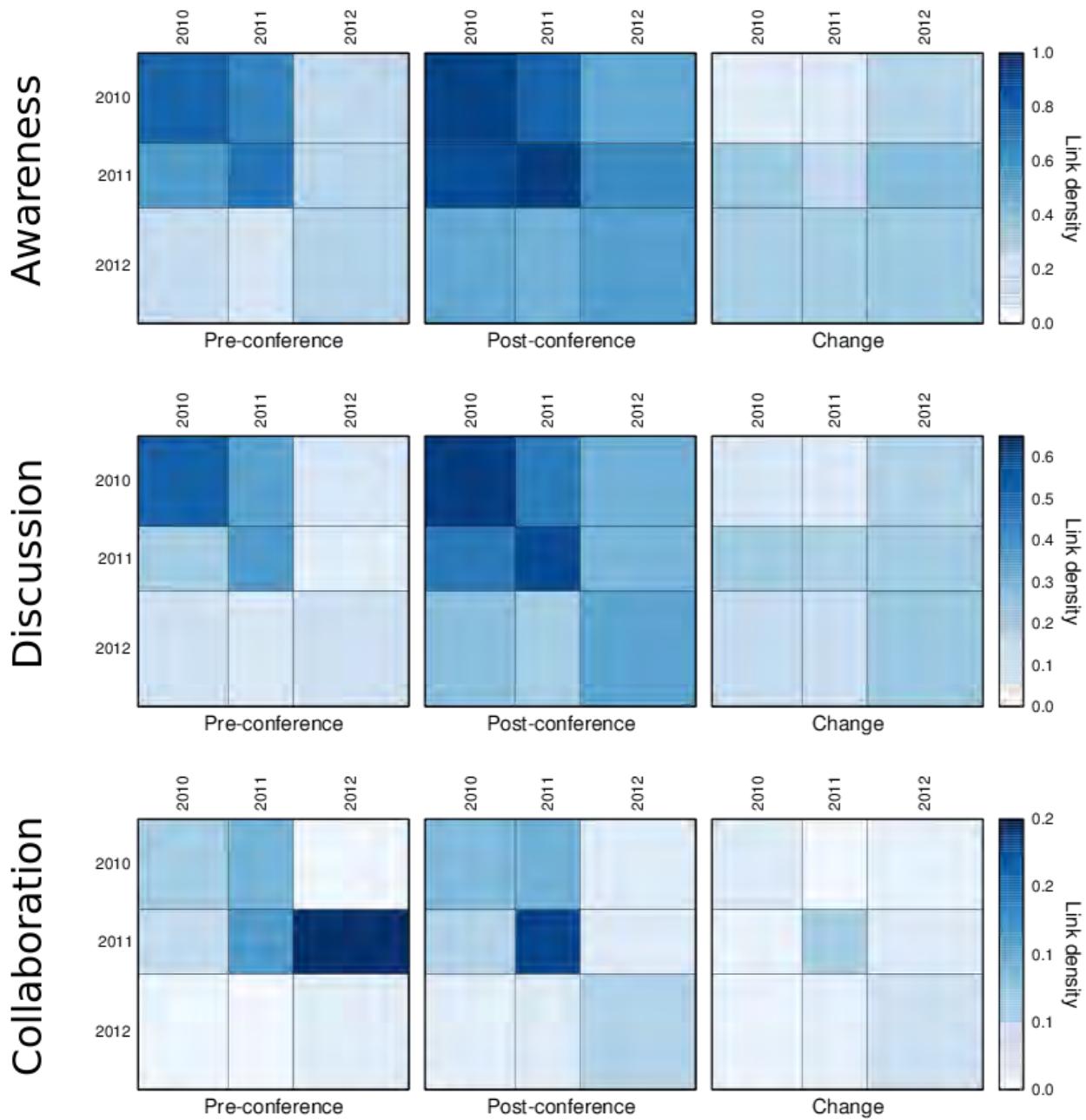
### **Unsiloed connections between Scialog classes**

Repeat conferences that have new additions to the conference always can introduce some biases among attendees; attendees may tend to associate with people they have already met at previous conferences. This effect --- known as "[siloing](#)" --- can greatly hinder the ability of Scialog to forge new collaborations among attendees from new classes of the Scialog conference.

Before the 2012 conference has even started, it is clear that the 2010 Scialog attendees will have more connections, for example, because they have already had an opportunity to interact at two conferences. Will the Scialog conference foster connections between all Scialog classes in an unbiased manner? Will the resulting post-conference networks remain somewhat siloed?

To address these questions, we measured the density of connections between all pairs of Scialog classes (Fig. 5). Our results indicate that connections among the class of 2010 are still the strongest, but that the change in connections during the conference is not biased toward any particular class. Indeed, it is remarkable how evenly links are formed across all pairs of Scialog classes.

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**Figure 5. Integration of the classes of 2010, 2011, and 2012.** Given that the 2010 and 2011 Scialog attendees have already had the opportunity to interact with other Scialog attendees, we quantify the extent to which the 2012 Scialog attendees interact with previous years Scialog attendees by measuring the change in [link density](#) before and after the conference for the *Awareness* (top matrices), *Discussion* (middle matrices), and *Collaboration* networks (bottom matrices). Each matrix illustrates the connectivity from the group listed on the vertical axis to the group listed on the horizontal axis. The area of each cell in the matrix is proportional to the number of connections between the respective groups. Darker blue cells have more links than lighter blue cells; note that the range of the link density colorbar changes from network to network. The pre-conference networks all have much higher connectivity between 2010 Scialog attendees (upper left-hand corner of pre-conference matrices) and the post-conference networks all increase the overall connectivity among all pairs of groups (post-conference matrices are darker), generally increasing the overall connectivity by the same amount (the change in link density is relatively constant). The one

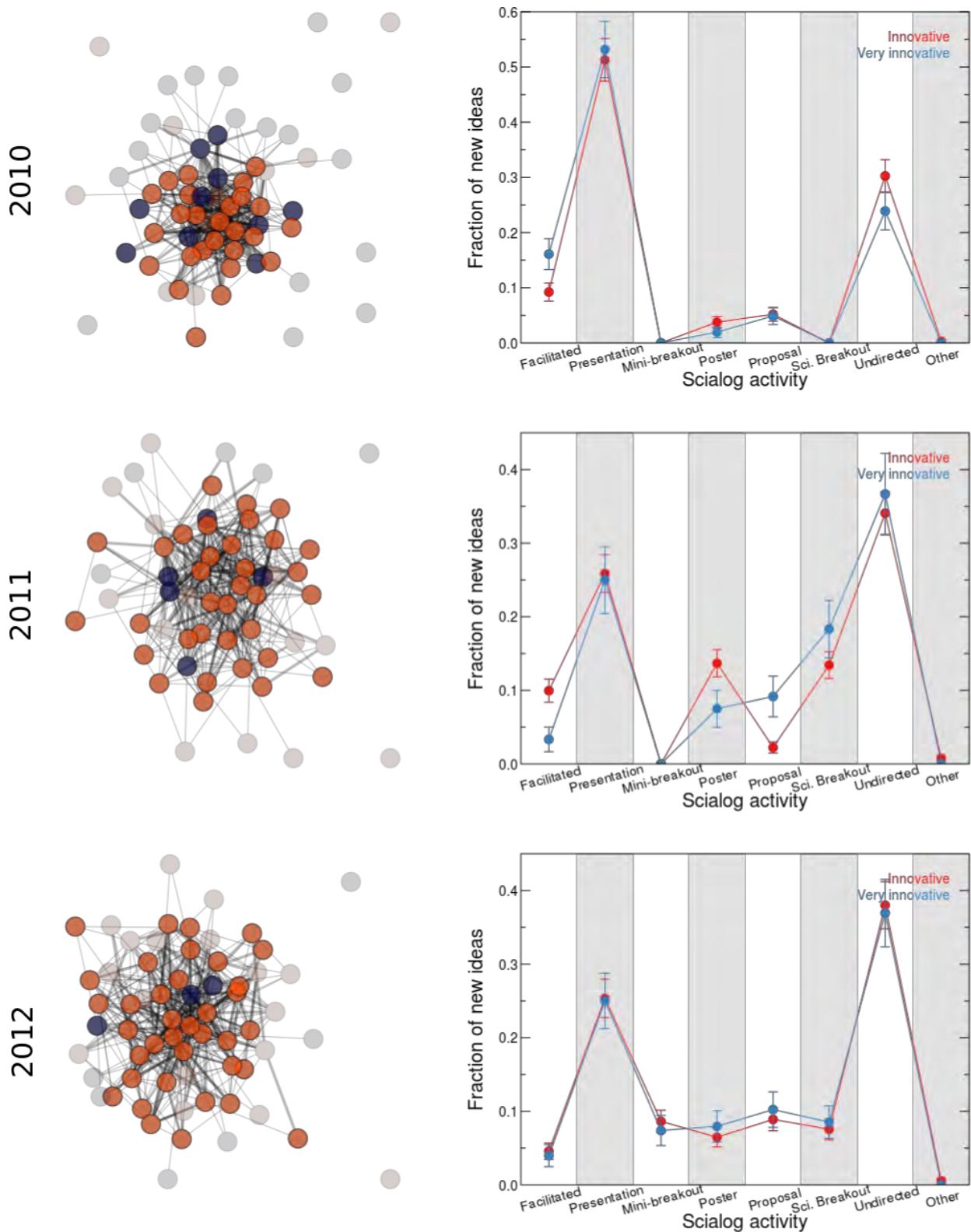
glaring exception to this observation is the change in link density in the Awareness network between 2011 Scialog attendees, which noticeably smaller than the change in link density between the other groups.

## Sharing ideas during Scialog

### Origins of idea network

One of the primary aims of any conference is to facilitate the sharing of ideas among attendees and the Scialog conference is certainly no exception. To assess the extent to which innovative ideas were shared among Scialog participants, we asked participants to identify individuals that shared *Innovative* or *Very innovative* ideas during the Scialog conference. Further, we asked participants to identify the Scialog activities that most directly led to the exchange of those ideas.

Scialog was again very effective in that, nearly every active solar energy researcher (orange circles) is connected in the idea network, indicating that the Scialog participants held each other's ideas in high esteem (Fig. 6). Interestingly, the majority of all innovative ideas were shared during formal presentations. In contrast with the widespread viewpoint based on empirical science education research that lectures (which are not terribly different than the uninterrupted, formal presentations given at Scialog) are not an effective way to teach students, this result suggests that formal presentations by experts to experts can be an effective means to communicate innovative ideas.



**Figure 6. Ubiquitous patterns of idea exchange.** Left: Circles represent Scialog participants, and lines between circles appear when at least one of the participants thought that the other participant's ideas were innovative. Orange circles represent participants that are active solar researchers and blue circles represent participants that are not active solar researchers. A faded circle indicates that the participant did not finish the survey. Line thickness

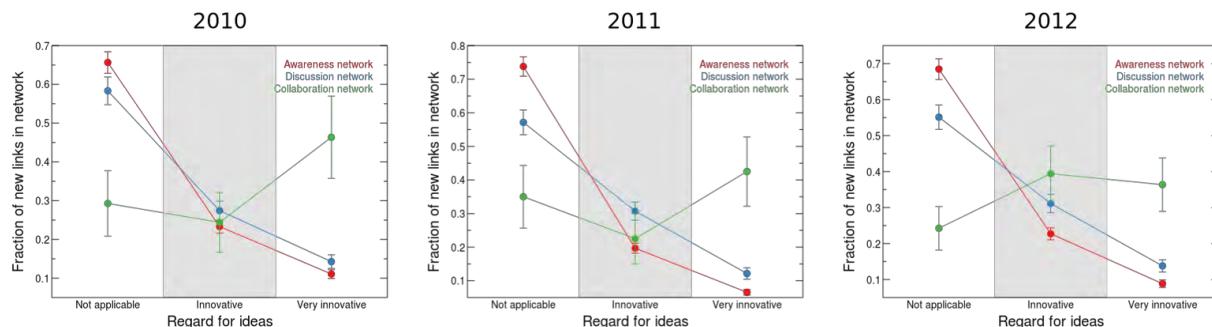
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represents the regard for ideas; thick lines indicate that one of the participants regarded the other participant's ideas as very innovative whereas thin lines indicate that one of the participants regarded the other participant's ideas as innovative. The regard for another participant's ideas is a crucial ingredient for collaboration, and there were very few active solar researchers whose ideas were not held in high esteem by their colleagues. *Right:* Given that one participant regarded another participant's ideas as innovative during Scialog, we quantify the activities that directly facilitated the new idea. Error bars are computed based on a [multinomial model](#). As was the case in previous years, there is no qualitative difference between the Scialog activities that facilitated the exchange of "innovative" ideas versus those ideas that were regarded as "very innovative." The results from this year are qualitatively identical to the results from last year (2011); most innovative ideas were exchanged during Undirected dialog, with presentations being the other primary activity where innovative ideas were exchanged.

It is also quite striking that there is almost no discrepancy between the activities that led to innovative versus very innovative ideas. While it is unclear whether this distinction was too vague for Scialog participants or whether this is truly an emergent pattern, it is still interesting nonetheless. Interestingly, these findings are amazingly robust between Scialog 2010, 2011, and 2012.

### Regard for ideas and relationship changes

Particularly at a research conference, the extent to which individuals interact is strongly affected by their interest in each other's ideas. Here, we examine how a regard for other people's ideas is related to changing connections during the Scialog conference (Fig. 7). Interestingly, the majority of awareness and discussion connections made during the Scialog conference had almost nothing to do with a regard for each other's ideas. In contrast, over 45% of collaborations occurred between individuals that thought their collaborator's ideas were very innovative, a pattern that is observed in both the 2010 and 2011 results.



**Figure 7. High regard for ideas tends to lead to collaborations.** Given that a new relationship of a particular type (*Awareness*, *Discussion*, or *Collaboration*) is formed during Scialog, we quantify the regard that the participants had for each other's ideas. Error bars are computed based on a [multinomial model](#). The same broad patterns emerge in 2012 as in previous years: *Awareness* and *Discussion* links that were formed during Scialog tended to not be influenced by the regard for another participant's ideas. In 2012 versus previous years, there appears to be no difference in new collaboration links based on whether ideas were considered "innovative" or "very innovative." However, Figure 6 suggests that there may be no qualitative difference in regard to the distinction between these two categories. If they are taken together, about 75% percent of new collaboration links are formed between researchers that regard ideas as innovative or very innovative.

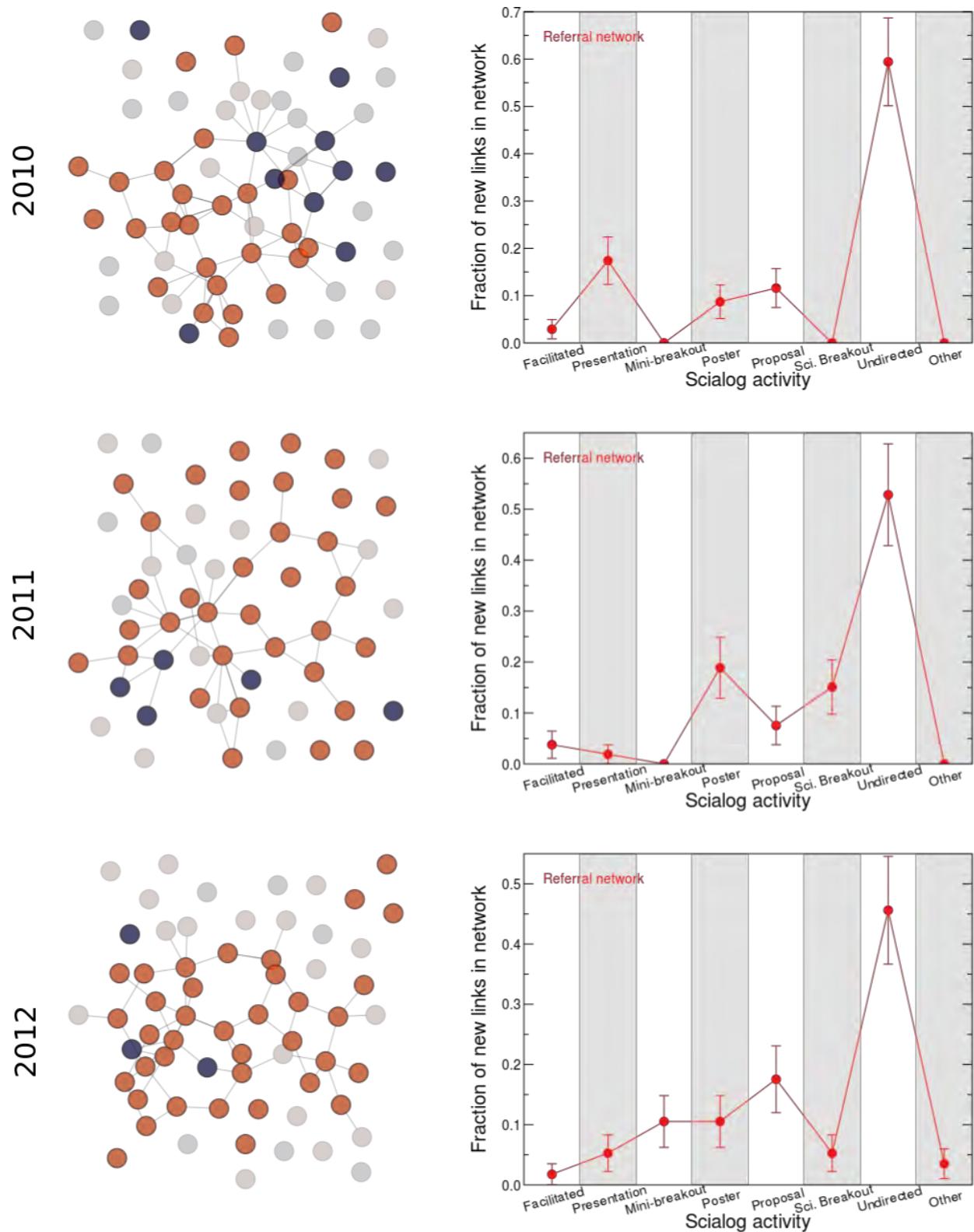
As another dimension of evaluation, it might be worth evaluating another dimension of collaboration in subsequent surveys --- camaraderie. Although this is probably not the primary driver of collaboration, it may be the case that persistent collaborations are not only the ones

that exchange interesting ideas, but also the ones that have an element of fellowship or sociability.

## **Building future collaborations during Scialog**

### **Beyond building direct connections**

Giving and sharing referrals among colleagues is an important part of any conference. Sharing references, expertise, or contacts is an integral part of being an academic. Referrals also offer a unique means to measure the impact of a conference beyond the walls of the lecture hall; how does Scialog impact the scientific community as a whole? We begin to address this question by asking Scialog participants to identify individuals with whom they exchanged referrals. Further, we asked participants to identify the Scialog activities that most directly facilitated those referrals.



**Figure 8. Referrals can lead to the growth of the impact of Scialog.** Left: Circles represent Scialog participants, and lines between circles appear when at least one of the participants gave a referral to the other participant. Orange circles represent participants that are active solar researchers and blue circles represent participants that are not active solar researchers. A faded circle indicates that the participant did not finish the survey. Referrals are a way that

networks grow beyond the boundaries of Scialog, and there were very few Scialog participants that did not indicate that they either gave or received referrals. *Right:* Given that a referral was made during Scialog, we quantify the activities that directly facilitated the referral. Error bars are computed based on a [multinomial model](#). Undirected dialog generated the most referrals, followed by poster sessions, breakout sessions, and proposal activities. In contrast with last year, formal presentations had little impact on referrals.

The emerging picture is that nearly every active solar energy researcher (orange circles) shared a referral with one of their colleagues (Fig. 8). Interestingly, nearly 55% of all referrals were facilitated by undirected dialogs. In contrast with the 2010 results, formal presentations contributed far less to providing referrals in 2011.

## Conclusion

After three annual Scialog conferences, a consistent picture is emerging. The Awareness, Discussion and Collaboration networks of active solar energy researchers who attend Scialog conferences undergo substantial growth in connections due to conference activities. Remarkably, proposal writing and mini-breakout sessions in particular have fostered new collaborations between conference participants who were often unfamiliar with one another prior to conferences. Although it is still early to determine if transformative scientific breakthroughs will be accelerated as a result of the growing number of connections mediated by Scialog conferences, it is certainly encouraging that these networks are becoming ever more robust.

## Appendix A: Survey questions

### Pre-conference questions

What do you consider to be  
your primary discipline?



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What do you consider to be  
your primary research area?



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Names are listed alphabetically. For each name please choose one answer that best describes your relationship with that person prior to arriving at this Scialog meeting. Note that this list is preloaded with your responses after the Scialog 2010 survey.

**Unfamiliar**

Choose this option if you are not aware of the research of the person.

**Awareness**

Choose this option if you know something specific about the research area of the person. Examples of "awareness" include you knowing that he studies visible-light photocatalysis or knowing the details of her last Nature manuscript.

**Discussion**

Choose this option if you have had substantive discussion(s) about research with this person, regardless of whether it is through face-to-face conversation, email correspondence, or other means. Please do not select this choice if you exchanged only basic information about the areas in which you work.

**Collaborator**

Choose this option if you have written a paper, book, grant proposal, or formally collaborated with this person toward a tangible research output. Please do not select this choice if you have technically collaborated but have never had a substantive research discussion with this person (e.g., coauthored a paper with 1,000 authors with whom you never interacted).



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Of last year's Scialog attendees, have you actually collaborated with any of them? Has there been any tangible research activity?



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**Post-conference questions**

Names are listed alphabetically. For each name please choose one answer that best describes your relationship with that person after participating in the Scialog meeting. You only need to modify relationships that changed during the meeting.

**Unfamiliar**

Choose this option if you are not aware of the research of the person.

**Awareness**

Choose this option if you know something specific about the research area of the person. Examples of "awareness" include you knowing that he studies visible-light photocatalysis or knowing the details of her last Nature manuscript.

**Discussion**

Choose this option if you have had substantive discussion(s) about research with this person, regardless of whether it is through face-to-face conversation, email correspondence, or other means. Please do not select this choice if you exchanged only basic information about the areas in which you work.

**Collaborator**

Choose this option if you have written a paper, book, grant proposal, or formally collaborated with this person toward a tangible research output. Please do not select this choice if you have technically collaborated but have never had a substantive research discussion with this person (e.g., coauthored a paper with 1,000 authors with whom you never interacted).



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For each relationship that changed, denote which part(s) of Scialog most directly facilitated the change.

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Please select up to ten Scialog participants for whom you gave referrals to a third party during the Scialog conference.

Examples include:

- You have offered to introduce this person to a third party.
- You have referred this person to a paper written by someone else.
- You have mentioned that a third party's work may be interesting for them.

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Names are listed alphabetically. For each person from whom you learned something you consider important, choose the extent to which their ideas were innovative and novel.

Please consider ideas about solar energy conversion, the Scialog meeting itself, the funding landscape, or any other topic.



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Which portions of Scialog are most directly responsible for facilitating the transfer of these innovative ideas?



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