Research Team Support & Development (RTS&D) at the Northwestern University Clinical and Translational Sciences (NUCATS) Institute

Second Annual International

Science of Team Science Conference

April 11-14, 2011

Chicago, Illinois

**In partnership with**

* NIH National Center for Research Resources CTSA Program
* NIH National Cancer Institute, Division of Cancer Control and Population Sciences
* Arete Initiative and the Institute for Translational Medicine, The University of Chicago
* Northwestern University, Office for Research

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**Executive Summary**

The Second Annual International Science of Team Science Conference was held on April 11-14, 2011, in Chicago, Illinois. The event was sponsored by Research Team Support & Development (RTS&D) within the Northwestern University Clinical and Translational Sciences (NUCATS) Institute on the Science of Team Science in collaboration with the NIH National Center for Research Resources CTSA Program and National Cancer Institute Division of Cancer Control and Population Sciences; the Arete Initiative and the Institute for Translational Medicine at the University of Chicago; and the Northwestern University Office for Research.

The 4-day conference was an open forum dedicated to the evolving field of the science of team science (SciTS), and brought together thought leaders from a broad range of disciplines, including translational research, communications, complex systems, technology, and management. The goal of the conference was to serve as a conduit between team science investigators and practitioners and leaders of team science, to engage funding agency program staff to provide guidance on developing and managing team science initiatives, and to afford data providers and analytics developers insight into team tracking and analysis needs.

Over 200 team science leaders/practitioners, team science researchers, tool developers, and funding agency program officers attended this event, which included three workshops, nine panel discussions, two keynote speakers, a poster session, several opportunities for meeting fellow attendees and networking, and team science tool demonstrations. Each panel session was followed by question and answer sessions.

In the one year since the first annual SciTS Conference, an active listserv with 250 subscribers was established; four manuscripts were published based on the conference proceedings; a Wikipedia entry on SciTS was posted; and a new journal title, *Clinical and Translational Science*, was introduced, as well as a special issue of *Small Group Research* dedicated to SciTS.

**Workshop: Leadership and Team Science**

Day 1 of the SciTS 2011 Conference was dedicated to a 3-part workshop on Leadership and Team Science. In Part I, Dr. Adam Galinsky discussed leadership skills for managing cognitive biases that affect information processing; techniques for constructively pointing out the errors in others’ logic; and skills for ultimately assimilating ideas and presenting a persuasive case to team members, deans, or external funders. In Part II, Dr. Brian Uzzi discussed techniques for building a better leadership network within and between labs and between scientists, university administrators, funding agencies, and donors. He also described three characteristics of powerful leadership networks, described a mechanism for attendees to measure their own networks, and discussed strategies for relationship and network building. Finally, in Part III, Dr. Uzzi led the group in an exercise to build a network among the workshop attendees.

**Part I: Leading High-Impact Teams**

*Adam Galinsky, PhD, Northwestern University*

*Professor, Management and Organizations, Kellogg School of Management*

Dr. Galinsky began his presentation by describing research on the most common cause of cockpit error by flight crews. It turns out that more errors are made at the beginning rather than the end of a flight, suggesting that fatigue or complacency are not the primary reasons that errors are made. Rather, more errors occur at the beginning of the flight, primarily because the crew may not yet know each other and are not able to easily coordinate their tasks. They do not know how to coordinate or adjust their behavior for each other. Richard Hackman described this as a self-correcting performance unit, in which individual team members are able to adjust their behavior in real time to accommodate other team members. Dr. Galinsky also described research that found hospital errors, particularly drug errors, are primarily due to miscommunication between doctors, pharmacists, and nurses. This observation has led to a change in healthcare such that health care staff are now structured as teams.

He asked the workshop participants to think of what has inspired, engaged, and excited them about team science: answers included the level of cooperation and buy-in, people wanting to cooperate, the belief in the mission of the team, the existence of a compelling goal, a leader who set a great tone (everyone’s ideas were respected, but everyone was kept on track with consistent communication regardless of changes in the project), a high level of trust, willingness to allow others to contribute while also being challenged, a feeling of real synergy—that people were able to transcend individual limitations to achieve something new. Dr. Galinsky then asked the attendees to think about a time in team science that made them feel morally outraged. Answers included: when team leaders played members off each other, political dynamics, team members working independently, selfish behavior, and lack of support or resources.

Some recurring themes included: the existence of cohesion and diversity as a source of tension in teams; without a clear goal, there is no cohesion within a team; and leadership sets the tone that overcomes roadblocks for teams. Once formed, teams move toward a norm of behavior as team members model after one another; if that behavior is bad or selfish, it can quickly overwhelm the team.

Dr. Galinsky defined leadership as the capacity to motivate, enable, and integrate a collection of individuals toward the success of a common goal or shared purpose. Leadership is a set of skills, and leaders are not born, they are made, and can come from anywhere within an organization to positively influence the group to achieve its goals. Notably, rank, position, and authority were not included in his definition of leadership.

He asked whether we can take the principles of general intelligence (the inference that people who do well on one task tend to do well on other tasks) and apply them to collective intelligence of teams. A study by Woolley et al (2010) found that the variables predict collective intelligence include a willingness to be open, the group’s structure (centralized vs. decentralized), communication, a common goal, and mutual respect. Interestingly, group satisfaction, cohesion, motivation, and personality did not predict greater levels of collective intelligence. Social sensitivity predicted a greater collective intelligence—social sensitivity is the ability to assess the mood of other individuals and adjust behavior accordingly. The study also used sociometric badges to track interactions and found that if a few group members dominated the conversation, there was less collective intelligence than if a few members were facilitating the interaction, but all individuals had input and the conversation was more evenly distributed.

A high-performing team must come together in a synergistic way to produce innovative solutions, but there must be buy-in from the members to move forward. There must be both—if there are just innovative solutions with no buy-in, then it can cause conflict, but if there is only buy-in, there is the risk of “groupthink” and the team may implode. Dr. Galinsky summed this relationship up in the following equation:

Potential productivity (can boost with diversity) – process loss (can minimize with cohesion) = actual productivity

Maximizing both cohesion and complementarity within a group of diverse individuals will produce high impact teams, whereas low cohesion/low complementarity creates pseudo-teams, high cohesion/low complementarity leads to groupthink, and low cohesion/high complementarity forms conflict coalitions.

Dr. Galinsky shared two videos on team strategies used by two very different companies: one group was very diverse, with no assignments, no leaders, and no hierarchy. The boss was not expected to come up with all the ideas, instead, the group brought in experts and drew on their insights. The second video described how Ingersol-Rand, a company whose employees traditionally worked in specialized “silos,” started a program with the goal to produce a new tool in 1 year rather than 4 years. They called people in from every part of the company, sent people to work in other departments, invited team members to outside events, asked for ideas, and met with end users to learn their needs. Both companies used team strategies that celebrated diversity, established clear goals and mutual respect, had the end-user in mind, and minimized hierarchy. The status of the group was maximized, there was a sense of play, and shared outside activities that built trust and cohesion.

**Q:** How does one overcome the inertia to get to a better team?

**A:** Use “set-up strategies”: ensure a team composition with cross-functional diversity, determine physical proximity; establish team-specific norms (e.g., own language, ways of working) and roles; identify shared goals; maximize the status of the group, but minimize status within the group; and plan shared activities. Also, recognize team processes: diversity and complementarity provide opportunities for unique information transfer among diverse teammates; and cohesion ensures trust in teammates’ credibility, accountability, intrinsic motivation, and social support.

**Q:** What parts of team work can be done in a distributed way (distance collaborations)?

**A:** We are impacted by those who are physically near us, in our immediate environment Hewlett Packard found that the most emails were sent to people on same floor. Other studies have found that once we move beyond 30 meters, influence is lost. Successful distance collaborations are also dependent on personalities and shared goals. In some cases, being apart can help people collaborate who do not like each other and shared goals can overcome distance.

Diverse groups produce more innovative ideas, but they also have more conflict and so require effective leadership. Diverse groups descend into conflict when leaders don’t communicate a shared goal and don’t encourage input from all members, don’t support or create opportunities for team members. With a shared goal, teams can avoid conflict.

One common problem among leaders is that they do not communicate why they want people to do things and they don’t share information. Why don’t leaders share their purposes? It is due to an illusion of transparency: leaders assume that their goals and intentions are apparent and obvious to others. Of course, this assumes that the leaders know their own intentions—sometimes they aren’t sharing because they are unsure.

Dr. Galinsky asked which person the audience found more helpful when waiting for a late plane at the airport: the gate agent who shares flight delay information every 15 minutes, or the gate agent who shares information only when new information is available. Even though he believes the former is more helpful, leaders may not provide good information until they know for sure, when instead they should be giving frequent updates and not waiting to communicate.

Dr. Galinsky then shared an exercise: he asked the audience to draw a capital letter E on their foreheads. It is possible to draw it in one of two ways—so that it can be read by others (other-focused) and so that it appears backwards by others (self-focused). Leaders often produce a self-focused E because they believe that others will automatically understand their perspective.

**Q:** Some leaders may feel that this kind of continual updating is a time constraint.

**A:** This may be due to both a personal issue of egocentrisim as well as a structural issue of time management. Leaders must build in opportunities to hear other team members’ perspectives; one way to do this is in an event outside of the team setting, such as picnics, golf outings, retreats, or barbeques.

**Q:** How much of our dependencies are based on a chain reaction? What about the concept of managing knowledge exchange?

**A:** You need multiple channels for communicating the same goal so that it is not distorted. Middle managers have a problem of having to look up an act a certain way, and looking down and acting a different way. Groups without a clear leader are harder to coordinate, and so the shared goal becomes even more important because it is the only mechanism to coordinate the team around.

**Q:** What about getting or giving feedback on the leadership – how do you understand our goal, what did you hear, what did I say?

**A:** Always test your assumptions with feedback.

Dr. Galinsky then shared a key message: People aren’t objects. If directives and force were highly effective, if those with less power simply did what those with more power told them to, then leadership would be simple. But force is an inappropriate way to lead people. The key role of a leader is to give team members opportunities to talk and create an environment where team members are empowered. People want to have a sense of control in the world.

What is the universal stated goal of the team? What is the best way to communicate it? Leaders need to open the right channels of communication and close the wrong channels. Every time you create a team, the team members must make a decision to opt-in or opt-out. If all you need is a team, form it with presumed consent (opt-out); but if you want a quality team, must have a clear, stated goal and have people opt-in.

What is the environment that will achieve that goal? He shared the 10 things that casinos do to encourage people to stay and gamble, and ensure that the volume of players will overcome the low odds in favor of the house. The question for team leaders is: how do I set up the environment so that the team I am working with will be successful?

As a leader, how do you get people to change? What made Martin Luther King’s “I Have a Dream” speech so inspirational and effective in rallying the troops and affecting change? He repeated the goal, reminding the group of the overarching goal; he had a concrete goal, a core message; he expressed a feeling of moving forward to a better place. Science team leaders must also move academics out of the evidence base and towards the emotion, the passion behind what they are doing. They must communicate a shared experience with everyone moving toward a concrete goal.

Dr. Galinsky asked: What is your goal for this meeting?

* To surface all available information so the group can make the best decisions – procedural tactics for improving group decisions – you as leader
* To get the group to reach a particular decision – influence tactics, you as politician

He then shared a clip from the film “12 Angry Men” and asked the attendees to note the procedural tactics (the rules that guide the group) and interpersonal tactics (who says what to whom and how they say it). Henry Fonda’s character sets up a voting strategy: he asks for a secret ballot to relieve public/peer pressure to conform; he creates personal accountability by making what was a team decision into an individual decision; he uses the reciprocity rule and gives up his vote while placing the burden of responsibility on the rest of the group; and he minimizes the consequences the vote to reduce the stakes.

**Q:** Would Henry Fonda’s strategy have worked if they didn’t have that initial conflict in the open air discussion?

**A:** He’s taking that time to recognize up front how people are arguing, and then he decides on his strategy.

**Q:** Are preliminary votes good or bad?

**A:** When you think is everyone is in favor, you might be able to get something done quickly or efficiently. On the other hand, you might also provide an anchor for everyone to defend rather than hearing others’ opinions and it may be harder to change or find innovation together.

He then shared 10 procedural tactics that influence group decisions:

1. Is there an agenda? It structures the meeting. Place important topics in the middle, and ensure your issue is there and that you know who is setting the agenda. Who speaks first is important for setting the tone of the meeting.
2. Where is the meeting? Is it on home-court or a neutral site to encourage cooperation? Also, people remember information associated with the place they learn it, but having meetings in the same places can also constrain innovative thinking.
3. Who is at the meeting? Never let an important meeting happen without you being present! Make sure that there is diversity of option and experts represented.
4. Pre-meeting discussions can be helpful to get a read on concerns, interests, allies, and things that might not be on the agenda.
5. Who sits where – seating potion determines leadership (head of the table) and speaking order (clockwise), and seating arrangements can encourage discussion and determine the level of collaboration.

**Q:** Is there a preferred place for the leader to sit?

**A:** As a leader, you have a choice regarding how you influence the group based on where you sit. That is your decision based on the particular team and whether you want to encourage participation by certain people.

**Q:** Making space for unspoken or minority positions can be encouraged by seating the leader to the side.

**A:** We see that in collective intelligence. If too many people dominate, you lose the minority opinion, so you have to make space, figuratively and literally.

**Q:** We’ve seen a tendency toward group think where the leader re-iterates a majority opinion and it gets entrenched.

**A:** But if you repeat minority opinions they can be heard better.

**Q:** How does a leader of a group manipulate the dynamics of who is coming to the meeting in order to facilitate discussion?

**A:** That’s why I think structure is so important. Once you’re in the meeting, the constraints and structure might break down, but you can set the tone as much as possible up front. There are two things that people do wrong in team meetings—no agenda and no tracking of information. These issues occur before and after the meeting.

Dr. Galinsky continued the list of procedural tactics:

1. Timing of vote – deciding whether to take a preliminary vote, shelve a vote, or form a committee
2. Voting format – whether to make it public or private
3. Decision rule – majority vs. supermajority vs. unanimity
4. Tracking information – who is chosen to take notes and will they be unbiased?

**Comment:** Tracking of information should occur in real time, rather than relying on the meeting note taker, because a misunderstanding or misinterpretation can be made concrete in the meeting notes and the nuance from the meeting is lost.

1. Length of the meeting and timing of breaks – use breaks to secure commitments or disrupt the influence of opponents. Breaks also allow people to digest the information that they just heard. The best decisions are made when there is an intense period of discussion and then time to think and integrate the information.

**Q:** What about group size?

**A:** Seven is the best, plus or minus 2, so groups of 5, 7, or 9 are the preferred sizes.

Dr. Galinsky then returned to the “I Have a Dream” speech and the scene from “12 Angry Men” and discussed tactics for delivering a key message: use simple, concrete messages with vivid stories; use a consistent message; use a loss frame to express what will be lost by not adopting an opinion; ask questions rather than asserting opinions so that opponents can discover your insights. Also, be seen as a credible source by protecting your credibility and undermining your opponents’ credibility. Don’t display your personal agenda, use anger rarely and direct it at the issue and not the person, remain collected and appear impartial, don’t make absolute statements (because they are easy to discredit), and maintain a consistent position and avoid being hypocritical. As for your opponent, highlight their personal agendas, inflame their emotional outbursts, lead them toward absolute statements that can be easily discredited, lead them towards and highlight their inconsistencies and any potential hypocrisy.

Dr. Galinsky also asked that leaders think about the audience: are they friends, foes, or fringe. He suggested that time is not well spent trying to influence your foes; rather, go after the fringe in order to build a coalition.

With regard to timing, consider when people are most receptive to hear information; in particular, people are more receptive to critical information after they have been praised.

**Comment:** If you really want constructive feedback, the ratio of positive to critical information should be 4:1.

The law of reciprocity – if someone does something nice for us, we will reciprocate. We can also give something up front and expect to get something back. A leader can get people to make small commitments first before asking for big ones.

Dr. Galinsky stressed that the audience members need to ask themselves if they are comfortable using a particular influence tactic; if not, they will spend a lot of cognitive energy dealing with the discomfort and will not be able to follow what is going on in the group. It is important to be aware of these tactics because someone may be using them against you, to influence you, and you must be ready to defuse their tactics.

Dr. Galinsky concluded with a comparison of the process characteristics between the teams involved in the Bay of Pigs and the Cuban Missile Crisis. Kennedy learned from mistakes in first team to create better conditions for second team.

**Part II: The New Science of Networks**

*Brian Uzzi, PhD, Northwestern University*

*Professor, Management and Organizations and Industrial Engineering and Management Sciences, Kellogg School of Management, and Co-Director, Northwestern Institute on Complex Systems*

Dr. Uzzi started by expressing that a new science comes about rarely, when people come out of their silos and come together. That’s what happened with the study of social networks in the last 5 to 10 years. There are a lot of disciplines coming from their own perspectives to converge on the same set of facts. He then asked, “What makes us so excited about social networks?” Achievement is associated with your own network – it is how you transcend your limitations—financial, organizational, and social—that allows you to succeed.

Dr. Uzzi shared the example of Paul Revere and William Dawes, and asked why is one known as a legend and the other is not, even though they did the same thing? Historians concluded that they had different networks. Most successful organizations—doctors, researchers, artists—have networks more like Paul Revere’s than William Dawes’. There is something powerful about how networks transform what you have into something more. During his presentation, Dr. Uzzi would cover the following topics:

1. What are the properties of these networks that make them so powerful?
2. What does your network look like?
3. What are the strategies for building Paul Revere networks?
4. How can we demonstrate the power of networks within this workshop?

**Properties of networks**

**Capital of Innovation:** what you bring into a team, and what everyone in that team also brings: their social capital. How much should I invest in my social network? If they are so important, they must give you something that is hard to get through other means: information, skills, leadership capabilities, etc. But you need to get people to join your networks.

**Information:** what is so dramatically different with information today that was different 5 years ago? Accessibility, volume, rapid pace. Information is standardized and 3rd party verified, which lets me compare and make decisions. The great irony is that we are living in an information paradox. The information is increasingly losing its value for us all. How long does it take for information on the Internet to double? Six months, and that’s not even with China and India online. But the more widely available something is, the fast it loses value.

The democratic Web is an attempt to stop that process, in order to hold the value, but it’s also put a premium on the value that we carry, the private information about us. It is eclectic information and we spend a lot of time trying to find out what that information has and who has it. The value of FB is that it has private information about all of us that marketers want. Private information is idiosyncratic and trust verified, meaning that the only way to figure out what information is right or wrong is by trusting the source and determining how you build trust with that source. There is a self-evident connection between trust and social networks: people tend to overbuild their networks based on trust, and it crowds out other potential relationships. Many people with fresh ideas often create rivals around them without even realizing it. You’ve got your eye on the right thing, but it’s threatening to others. One strategy for building Paul Revere networks is to build relationships with those that see you as a threat.

**Skills:** this refers to human capital – degrees, training, and expertise. In the last 10 years, the world has been changing dramatically in terms of silo-ization. Universities are training narrow but deep specialists. The amount of information has grown so much that it has been impossible to learn it all, leading to specialization. The Web of Science has shown an exponential growth in the number of published papers. There are more and more PhDs given in increasingly specialized areas. This is leading to formation of multidisciplinary groups – and the more diversity in the teams, the better. You want a network with nodes that are different from you and different from each other. There has been a universal growth in team science, and universal increase in the impact of teams over the impact of individuals (in terms of citations). The higher team impact is due to diversity, as the more impactful papers bring together diverse knowledge.

**Q:** If we are conscious about forming our networks, we need to know what others networks look like. How do I know this?

**A:** You need to know as much as possible, but there are strategies you can use to learn more about your network. LinkedIn’s value is centered around that need to know.

**Strategies for building Paul Revere networks**

Dr. Uzzi described that once social networks are mapped, they reveal clustered patterns—cliques or “echo chambers”—that are not valuable for teams. These clusters represent a homogenized point of view, a common information effect or bias toward exchanging information they have in common rather than expressing their differences. It robs diversity from the network structure. The trust-diversity paradox underlies this tendency towards clustered networks. There is an inverse relationship between trust and diversity: it is easier to trust those who are like us. When we choose only people we trust, we choose people that are like us and end up crowding out diversity. The world is self-organizing in this way, so how do you get out of a structure like this? You can take advantage of how the network comes together to overcome this structure.

**Comment:** In the Hewlett Packard labs in early 80s, the best leaders were those who left their offices and the executive suite bubble and walked around.

**A:** The purpose is to get at private information just by bumping into people who are outside of your network.

Individual power: who gains power around us?

1. Pyramid corporation, formal power and directives, standard procedures
2. Pancake corporation, network-based, rainmakers, opinion leaders, connectors

The single common denominator that goes across all power are *brokers*. A broker is not in a cluster but someone who bridges clusters. This concept goes back 50 years to research by Stanley Milgram. He also coined “six degrees of separation” in his experiment that showed that one stockbroker in Boston was connected to 160 people in Omaha by an average of six people, but that 60% of the paths went through 4 superconnectors or “brokers.” Who were the 4 superconnectors? What made them special? They tended to be people who came into contact with a cross-section of people and they did not tend to self-select the people they came into contact with. By breaking down self-selection, we can create better networks. The 4 superconnectors were an attorney and traveling salesmen.

Trust, diversity, and brokerage are the keys for a powerful network. Paul Revere spoke to brokers, who then spread the message to their networks, whereas William Dawes spoke to people who were in the same networks, and so the message did not spread, it just circulated in networks. The value in FB for marketers are those brokers who will ensure reverberations of information through the Web.

**Q:** Do you want to be Paul Revere or know people who are Paul Reveres?

**A:** Both

**Q:** Are there personality types that are more likely to navigate this world as a Paul Revere? You might be less comfortable interacting with cross-sections. There is also a cognitive aspect as you try to navigate across specialties. Curiosity might be an attribute that encourages this.

**A:** The caveat is that there are so many personality types that we wouldn’t know where to start. The personality correlates with social capital. A person’s personality inventory accounts for 13% of their network. People who are charismatic have bigger networks, but they may just have bigger echo chambers. Some highly specialized people may be in small but diverse networks. The key is bringing people into your network who bring in what you don’t have.

**Examples of networks**

Goldman Sachs uses groups for short-term projects, so you can map how networks form based on participation in these teams. They are also supposed to rate everyone you work with in terms of how much you trust them. Dr. Uzzi looked a Paul Revere and a William Dawes and kept everything else constant, and found that Paul Reveres got higher salaries and bonuses.

Dr. Uzzi also found that papers with co-authors who had broker ties were more impactful papers than those with clusters of authors.

Halliburton assessed their network and found that they had too few brokers, and too many geographic holes. They changed only the network to include more brokers, gaining a 25% improvement in degrees of separation, and significant improvements in performance.

In a high school dating network, the brokers that held the network together were involved in multiple groups that didn’t necessarily go together (captain of the football team and math team, cheerleader and glee club, etc.)

Because Typhoid Mary connected so many separate networks, she was more effective in spreading typhoid across Manhattan. The same kind of situation was seen with SARS transmission, which spread by a few brokers who crossed communities.

**Q:** Brokers can be highly valuable but also highly dangerous depending on the context.

**A:** They can be.

**Part III: Six Degrees of Separation Exercise**

*Brian Uzzi, PhD, Northwestern University*

*Professor, Management and Organizations and Industrial Engineering and Management Sciences, Kellogg School of Management, and Co-Director, Northwestern Institute on Complex Systems*

**How diverse is your network?**

In part III of the workshop, Dr. Uzzi introduced the “Six Degrees of Separation” worksheet, and asked attendees to list out their contacts and identify who introduced them to that contact, as well as who they introduced that contact to. In this way, each attendee would be able to map out their network and identify the brokers.

The self-similarity principle states that people have a high propensity to connect with people like themselves. This has more to do with training and background for this audience. People do this so much, but what do we get out of it? It is an affirmation, it’s easy, it uses the same language, and does not challenge core beliefs, but the most important is trust. We rarely communicate clearly, we’re always talking in code, and to understand others we rely on using the same code. We don’t build relationships unless we want something—utility is always in mind. There is also the joy of spontaneous agreement—we click more often with self-similars. Statistically speaking, we will have this ego-satisfying experience with people who are like us. We need it to build confidence, but there are limitations. Once you break that 70% threshold, you lose access to discrepant information, and you are less able to learn, problem solve, and be creative because you have put yourself in an echo chamber. When you unobstrusively measure who is interacting with each other, like is attracted to like.

The proximity principle describes a tension between efficiency and creativity. The world organizes things by likeness—departments, groups, labs—and we populate our network with people who are just like us. The frequency of interaction initiates relationships, but creates echo chambers. How do we get out of this?

The shared activities principle gives you everything the self-similarity principle gives you without any of the drawbacks. It solves the trust/diversity paradox and builds Paul Revere networks. Examples of shared activity include team or partner sports, participation in volunteer or community service groups, and formation of cross functional teams. There are three properties that maximize shared activities: **Passion** – busy people consistently make time for their passions; **Interdependence** – at least two people are needed, must be satisfied by someone else; **Stakes** – must have something at stake, gradation of winning or losing. Shared activities **increase diversity** by involving a cross-section of people engaged in the same activity and break down self-selection. These activities also e**ngender trust.** People are bound by a common goal or common theme that trandscends the person and is based on skills. This involves profiling and perceived transparency of a behavior or characteristic; essentially, a leap of faith that the person I see during this shared activity is the true person, a more spontaneous person. Bonding is fostered when you celebrate victories and commiserate over defeats. Personal scripts, a set of expectations that we all share when we interact with each other, are established. This all drives networks to achieve brokerage, which is trust plus diversity.

The key message: It’s what you do that defines the network that you’re in, and the shape of your network can determine your success, even when you do not change.

Dr. Uzzi gave a final example of the power of brokers within the world of corporate alliances in the telecommunications/entertainment industry. Bill Gates and Warren Buffett shared a love of bridge and that was the basis of their relationship. Even before he was a household name, Mary Gates’ mother sat on many non-profit boards, including IBM, where she happened to talk to Richard Akers. All of a sudden IBM started taking proposals from small companies, including Microsoft. Mary Gates was the broker in Bill Gates’ network that got his sensational idea realized.

**Demonstrate the power of networks**

Dr. Uzzi continued the workshop with an exercise in which he asked everyone to write down a wish and what they needed to make the wish come true, as well as how much time and money they were willing to spend on achieving their wish. He also asked that they write down their names on the top edge on 5 post-it notes.

Dr. Uzzi went through the room and asked each person their wish and what kind of person they were looking for the help achieve the wish, and then asked the room if anyone knows that kind of person. If so, the person was to add the wish-maker’s name under theirs on one of the post-it notes. Dr. Uzzi then placed the wish on a “Reciprocity Ring” on the wall. Workshop attendees wished for everything from flying lessons to a part in a movie to recommendations for a birding guide in Costa Rica to a spot in President Obama’s weekly basketball game.

Next, attendees were asked to put their post-it notes on the ring next to the wish they thought they could help grant, and were given a gold button for each post-it note. The brokers in the network could be identified based on the number of gold buttons they had. Several people had 5 buttons, one had 6, one had 7, one had 9, and one had 19. This activity was originally discovered in the Kula tribe by the anthropologist Margaret Mead. The “Kula ring” could be used to grant wishes as long as people could reciprocate. The participants were encouraged to follow up with people who said they could help with the wishes.

**Keynote: Team Research to Inform the Science of Team Science**

*Eduardo Salas, PhD, University of Central Florida*

*Professor of Psychology, Industrial/Organizational and Applied Experimental and Human Factors*

Dr. Salas finished graduate school in 1984 and went to work for the Navy as part of a team of organizational psychologists studying stress and team training. About five or six years ago, he opened a file from his Navy days and re-read a review article that summarized team performance from 1955 to 1980, and is organized around seven questions (Dyer JL. *Human factors review*. Santa Monica, CA: Human factors Society. 1984. p. 285-323.). The Army funded Dr. Salas’ group to do massive review of team science continuing from 1980 up to 2009. Dr. Salas shared some of the key findings from the 2-year project.

**Who cares about teamwork?**

The military (DOD) is the largest stakeholder, and funds a lot of research on teams. The FAA and the airlines are also interested in team training and crew resource management. The third interested party is the oil industry; there are 1800 oil rigs in the Gulf of Mexico, and every time there is a hurricane, there are 80 people per platform to evacuate, and effort that requires massive team coordination. Healthcare is another big funder of team research; they have an obsession with team work, especially in hospitals, and the AHRQ and DOD have put a lot of money into team training of health care workers. Another group are emergency response teams that deal with national disasters and must bring together many different agencies to respond. The sports literature is full of team studies. Every successful coach has a book with at least one chapter dedicated to teamwork. Bill Parcells wrote a Harvard Business Review article on teamwork, how to manage people with big egos and salaries and bring them together into a team. Team science is a very complex area, with many resources, and Dr. Salas expressed his amazement that researchers are still trying to get their hands around it.

**What is the State of the Science of Team Science?**

Dr. Salas’ review of team science since 1980 resulted in a database of 1255 articles, of which 731 are empirical, 150 are truly experimental, and most are self-reports. Topics could be grouped into work structure; individual, task, and team characteristics; training and intervention; processes; measurement; emergent states; and organizational, team, and individual performance.

**What do we know?**

***What theories have been proposed to account for team behavior?***

In 1984, the theoretical base regarding team behavior was meager, with mostly descriptive literature. In 2009, we have 140+ theoretical models, the majority of which reflect an I-P-O framework. Models include Group Effectiveness models, the Time and Transition model, the Team Evolution and Maturation model, the Flightcrew Performance model, and the Big 5 teamwork dimensions (team leadership, team orientation, back-up behavior, adaptability, and mutual performance monitoring). Emerging theories are more contextualized and integrated, increasingly multi-level and cognitively grounded, temporally based, and cognizant of developmental stages. Furthermore, the field is truly multidisciplinary, from psychologists and social scientists to architects.

***What types of tasks do teams perform?***

In 1984, the overlap among approaches was difficult to determine and there were no guidelines or systematic attempts to apply approaches to teams. In 2009, there is a wide variety of tasks with more typologies. Teams perform tasks that vary in complexity, have competing goals, and differ in the level of interdependence.

***How do teams function or work? By what means or processes do they achieve their goals?***

In 1984, goals were achieved “through teamwork.” It wasn’t well defined and there was little research on how team members interact, the important contextual factors, what team members learn over time, what behaviors are needed for successful teams, and the role of the team leader. In 2009, we know a lot more, but the question is, “How do we turn a team of scientists into a scientific team?”

We must understand the phenomenon, know how to measure it, and then know what to do based on that measurement. The field has moved to answer these three questions. Many team science researchers are looking at measurement specifically, or how to assess teams. Team training and management is also a rich area of research. Following team processes shows a positive correlation with team outcomes, communication, coordination, leadership, decision making, potency and collective efficacy (belief that team members have to achieve the task, confidence) shared mental models, and trust. Time matters in terms of when interventions should be delivered, when teams are likely to adapt, the cyclical dynamic nature of team process and performance, and members’ orientation to time. Teams adapt and adjust strategies and self-correct. More communication is not necessarily better. Talking can be costly and must be effective to keep from being an obstacle to success. Team leadership matters and must be task- and behavior-focused. Shared cognition is multi-dimensional, psychological safety impacts team learning, and situation awareness matters: knowing what you know and knowing your environment is important to decision making, team performance, team coordination, and facilitating transference of leadership. Trust is essential—it is what glues the team together. It allows development of psychological safety, facilitates conflict resolution, fosters continuous learning and adaptation, facilitates adaptive coordination, helps interpret monitoring and back-up behaviors, and determines the degree to which team self-correction will occur.

We also know that teamwork skills are distinct from task work skills, that teamwork is a set of inter-related competencies, and is a dynamic, episodic, and multi-level phenomenon.

Dr. Salas shared “The 6 C’s of Teamwork”: cooperation (motivational drivers), coordination (behavioral mechanism), communication (informational protocols), cognition (common understanding), coaching (leadership activities), and conflict (resolution procedures). Team leaders are coaches in a real sense. They foster performance, create a climate for team to flourish. There are two other C’s: culture and context (the organization and tasks, geographic location, environment).

Dr. Salas stated that the main problem with every team he has seen is that team members do not have defined roles and responsibilities, and do not know their place in the team or why they are there.

***What do effective teams do, feel, and think?***

They hold shared mental models, with members who anticipate each other and can coordinate without overt communication; they optimize resources, with members who self-correct, compensate for each other, reallocate functions, and adapt performance strategies; they have clear roles and responsibilities; they have a clear, engaging, valued, and shared vision; they have strong team leadership (many behavioral characteristics); they engage in a cycle of pre-brief-perform-debrief; they have a strong sense of the “collective” that relies on trust, teamness, and confidence; they are workload “sponges” that tolerate stress and can shift to accommodate activity; they set expectations, engage in rhythms of performance, and manage and optimize performance outcomes.

***What factors influence team performance?***

In 2009, research has identified what matters: the organization, policies, incentives, leadership climate, and human-systems integration. We must be able to measure these and then apply what we find to team training.

***What has been the impact of military training programs on team processes and performance?***

Team training works, but works best when it is based on sound theory, is systematically implemented, and uses the appropriate balance of tools, methods, and content. Dr. Salas’ group looked at 45 studies and 93 effect sizes to assess the relative effectiveness of team training on cognitive, affective, process, and performance outcomes. He found that overall, team training had a moderate, positive effect on team function. The training content, team membership stability, and team size impact the effectiveness of team training interventions. Team training can explain 12% to 19% of the variance of a team’s performance (meaning fewer medical errors, more lives and aircraft saved, and a higher bottom line).

**Practical Advice**

Do a team diagnosis: ask what do we need to stop, start, improve, and continue?

Train your teams, debrief to ask what worked, ensure role clarity, use simulation, create psychological safety, establish common ground, and agree on team-based goals. Team leaders should provide situation updates, be the first to self-correct and set the climate.

Looking forward, Dr. Salas stated that the field of team science needs longitudinal studies, examinations of task interdependency and broader team types, methods for real-time measurement, application of multi-level theory, a proportionate mix of lab and field work, and more varied measurement with less self-reporting. Emerging areas of team science include multicultural and multinational teams, team adaptation, modeling of team behavior, human-computer teams, sense making and information fusion, team leadership, and team cognition.

**Question and Answer Session**

**Q:** What accounts for the 80% of team performance beyond team training?

**A:** Organization, but also leadership and how it is aligned, what signals are sent and what policies are set. Team training itself will not solve team problems.

**Q:** Scientists complain that teams are a large draw on their time. What can you say to that?

**A:** It takes some effort at the beginning to establish a good team. We weren’t trained this way, we value solo accomplishments and publications. There is always push back at the beginning, but once the concepts are established, and you get success, then people will buy in. It is helpful to pre-brief and then if it doesn’t work, debrief. It will take time to move our research culture toward team-based models. Healthcare is beginning to move that way and research will too.

**Q:** How do you define “team?” A lot of scientists are in distributed teams that look like networks of communities and not tight-knit teams.

**A:** The literature defines teams from groups: high task interdependency, tasks are well defined…but most of what I talked about today was applicable to larger, more dispersed teams. The higher the task interdependency, the less the interpersonal issues matter. The less task interdependency there is, the more the interpersonal issues matter.

**Q:** Is there a difference in team formation based on the type of tasks – physical vs. mental?

**A:** I have not looked at that. There are things that are generalizable regardless of the type of task, particularly if there is high task interdependency.

**Q:** As the number of inter-professional teams and projects grows, what are unique aspects that need to be addressed and might differ from more homogenous teams?

**A:** Establish common ground. The PI as the team leader must provide situation updates and set the climate up front. In particular, psychological safety needs to be established up front. Role clarity is also essential.

**Panel Session: Evaluation of Team Science: A Multilevel Systems Perspective**

The panel considered major challenges in the evaluation of team science, examining the local, interpersonal and network level and the broader macro level of big science and translational research. Panelists also discussed the role of social and knowledge networks in shaping the assembly of scientific teams and how these network influences imprint their subsequent performance. The panelists suggested how evaluations can and should address local needs and stakeholders, in particular the scientist managers who are asked to lead complex team science initiatives. Finally, the panelists assessed the challenges and benefits of incorporating a “systems perspective” in the evaluation of team science that addresses interpersonal and network perspectives, multiple stakeholder views, and process assessment at multiple levels.

**Evaluating the Local Context of Interdisciplinary Team Science**

*Jacob Kraemer Tebes, PhD, Yale University*

*Associate Professor of Psychology in Psychiatry, Child Study Center, and Epidemiology and Public Health*

Dr. Tebes acknowledged that science is perceived as an individual endeavor, and that discovery is individual. But there has been a growth of team science since 1960 (Wuchty et al. Science 2007), even though science done in teams is probably more difficult. He asked, What kinds of consortium activities can capture that moment of discovery?

Dr. Tebes used the Interdisciplinary Research Consortium on Stress, Self-Control, and Addiction (IRC) as an illustrative example. The IRC examines stress and its relationship to addiction, alterations in brain chemistry, and stress modulation and behavioral control. Nearly 20 disciplines are involved, though it is heavily oriented toward neuroscience, psychiatry, and psychology. The IRC is one of nine national consortia funded by the NIH Roadmap grant, with 3 sites and 80 scientists working in 20- to 30-member work groups focused on particular topics. There are three cores, nine R01s, and an R25 education program. The IRC holds various meetings and seminar series, and conducts interlab training, informal communications, and site visit preparation meetings.

In terms of evaluation, there are several underlying assumptions: team science involves collaboration, yields innovations, is facilitated by specific interpersonal transactions, and is an exemplar of micro-level research within a multilevel systems framework (Börner et al. 2010). Therefore, various measures must be evaluated, including collaborative readiness, activity, and interdisciplinarity; team climate; affective climate; satisfaction; precursors to innovation; and scientific innovation.

The relationship between these measures stems from the assumption that interdisciplinary collaboration accelerates scientific innovation. Precursors to innovation include team climate and affective climate, satisfaction with the consortium drives the climate, and all of these aspects are ultimately based on the structure of the consortium itself.

Dr. Tebes then shared the results of the 2-year IRC evaluation. With regard to the characteristics of the IRC scientists, there were more female scientists, and those who had a certain level of interdisciplinarity at the start of the IRC were more likely to continue interdisciplinary research. He also tracked density and closeness of the social network within the consortium, and found that the increase in closeness within the network leveled off after one year. Likewise, interdisciplinarity, climate, and satisfaction all leveled off by one year. The exposure to divergent points of view increased up to 18 months and was highest in work groups and across the consortium, and to a lesser extent in local teams. Distributed and analogous reasoning was also less evident in local teams. However, the use of unexpected findings was greater in teams. In general, the teams tend to level off unless new blood or new ideas are introduced.

Dr. Tebes also conducted interviews with consortium members to gather qualitative longitudinal data. He asked questions like “How has the IRC supported or hindered your capacity to make intellectual contributions, innovations, or discoveries? Three themes emerged: that the consortium provided tangible support and structure; allowed direct access to new collaborators; and facilitated access to new ideas. As an example of the evolution of feedback over time, Dr. Tebes shared the actual comments from one investigator’s interviews: in Year 1, investigators felt supported by the IRC but that it was also time consuming; in Year 2, the IRC was complicated but allowed direct access to new collaborators; and in Year 3, the IRC shortened the time between idea generation and doing the research, connectedness helps ideas come to fruition.

Dr. Tebes summarized the implications of the IRC evaluation. First, the IRC is an ***emerging heterarchy***, meaning that it is structured but not hierarchical, has interconnected and overlapping components, and the overall dynamics of system govern the interactions between the components. Some examples of emerging heterarchies include individuals acting as dynamic members of interrelated groups; biological signaling processes; evolutionary systems; participative democracies; and Wikipedia. Kessel and Rosenfield have argued for heterarchy as a guiding framework for interdisciplinary team science. Such a framework would

* Promote a culture of research practice that values and rewards interdependent skills and expertise essential to a strong team
* Emphasize interpersonal processes that enhance the sustainability of scientific interdisciplinary collaborations
* Encourage the creation of funding that incentivizes interdisciplinary collaboration and team science
* Encourage interdisciplinarity and multiple stakeholder involvement (e.g., researchers, service recipients and providers, funders, policymakers) in the research process
* Encourage the development of institutional structures within academia and by funders to promote team science

**Understanding and Enabling Team Assembly**

*Noshir Contractor, PhD, Northwestern University*

*Professor, Industrial Engineering and Management Sciences, Communication Studies, and Management and Organizations*

Dr. Contractor started with some humorous examples of tools developed for network level analysis: the SNIF—social networking in fur—tracks interactions between dogs; and the Lovegety—is programmed with the preferred food, music, and movies of the wearer so that when they walk around, it goes off when it is near a match or potential love connection. Students were asked if they’d use it, and interestingly, men and women were equally likely, but engineers were more interested in it than were social scientists.

In all seriousness, though, Dr. Contractor asked, “How do we find the people we want to collaborate with in teams, and then how do we take what is working and not working and make team formation better? For virtually all fields, the number of interdisciplinary teams—particularly virtual, distributed, interdisciplinary teams—is growing. “Virtual team science” is occurring with significant geographic distribution. When these teams do well, they are very high impact, but only a few of these teams are able to achieve that success. Most teams flounder. So the question becomes, how do we matchmake to create more of these highly impactful teams?

There are multi-theoretical, multi-level (MTML) motivations underlying team assembly, including theories of self-interest, social and resource exchange, mutual interest and collective action, contagion, balance, homophily, and proximity. Some of these theories lead to productive results, while others do not (e.g., homophily may not lead to innovative thinking). Each of these MTML motivations has a network “structural signature” that can be mapped and help with understanding why we create certain networks or teams.

Dr. Contractor introduced the “Group Staffing Riddle,” which describes the tension between creativity and cooperation: we want to have highly productive teams based on diversity of expertise and cognitive models, but we also want smooth coordination and communication among team members with shared cognitive models. We can assess previous collaboration, current collaboration, and team performance to discover how prior co-authorship and citation network configurations influence team formation and success in scientific groups. The theoretical background for this type of analysis includes transactive memory, or the shared cognitive/mental models of “who knows what;” prior collaboration, or the likelihood of preferring partners with whom members are already familiar from prior work on joint projects; and homophily, or the tendency of individuals to interact more with those to whom they are similar.

He then shared three exemplars of his group’s research:

1. Team assembly for interdisciplinarity in NSF proposals – how did the teams assemble and what are the factors that drove performance? They looked at 1103 NSF proposals awarded and unawarded, and 2 interdisciplinary proposals over 3 years, comprising 2186 PIs and co-PIs. They found that researchers were not likely to randomly form a project collaboration relationship with each other. The numbers of single author proposals and big research teams were larger than random chance. Researchers from top-tier institutions and a high H-index were less likely to collaborate, whereas researchers with high tenure were more likely to collaborate and do so with those with whom they have previously co-authored or cited. With regard to funding, females were more likely to be funded on a collaborative proposal, and the odds of collaborating with a previous co-author on an awarded proposal is 4 times higher than collaborating with someone else. However, the odds of collaborating with a previous co-author on an unawarded proposal was only 2.5 times higher. ***Researchers are more likely to collaborate on awarded proposals if they have collaborated before (as co-authors) and if they come from different research areas (not citing each other).***
2. Team assembly of pilot grants in clinical and translational sciences (NUCATS) – the study consisted of two rounds, the first included 103 researchers in 59 teams in 37 departments, with four funded projects; the second included 73 researchers in 41 teams, with three funded projects. They mapped co-authorship and co-proposal networks, and then performed an estimation analysis. They found that researchers were not likely to randomly collaborate, female researchers were more likely to collaborate, and researchers were more likely to collaborate with co-authors with whom they collaborated before and who have the same level of expertise. Differences between round one and round two suggested that the NUCATS investigators learned what worked in round one and then selected different collaborators in round two.

Among the successfully funded researchers, those with higher seniority (as calculated by the numbers of years since they earned the PhD degree) were more likely to collaborate, but there was no such tendency in the unfunded group. This may indicate the importance of senior researchers when assembling promising groups. Among the successfully funded researchers, those who did not tend to cite each other but did coauthor with each other were more likely to collaborate. Again, there was. But there was no such tendency in the unfunded group, and it may reflect the funding agency’s preference for both multidisciplinary research and some collaboration history.

1. Dr. Noshir then described the construction of a recommender system for team assembly based on the round one estimation results in clinical and translational science. His group was able to predict all 8 successful grant proposals based on the estimation analysis. From this research, they developed the C-IKnow Sematic Recommender that asks researchers about what is motivating them in order to form a team. He showed a demo based on the NUCATS data. Importantly, all the data is stored in RDF triples as part of the Semantic Web.

**Evaluation of Team Science at Multiple Levels: The View From Cooperative Research Centers**

*Denis Gray, PhD, NC State University*

*Professor, Department of Psychology, Psychology in the Public Interest*

Dr. Gray moved to an even higher level of team evaluation, that of organizations. There are “meta-evaluation” challenges at this level, including that what qualifies as team science is not well defined, and although teams are expected to produce better science, that is also not well defined. It is also not clear what makes team science effective at the organizational level and who the stakeholders are.

These challenges and the myth of homogeneity has been dealt with by social scientists for some time. What does it mean for team science to be effective? The question is too broad. The more precise question is:

Is this type of *TS [informal, organizationally formalized; small scale, large scale; multi-, interdisciplinary]*, delivered by this kind of *[university; universities, disciplines, faculty, student]*, involving these stakeholder groups *[university, industry, government, and/or advocacy, discipline]*, catalyzed by this kind of leader, within this type of organization, with this kind of collaboration, effective in reaching this goal *[research, technology transfer, economic development, education]*, as assessed by this kind of measure, over this time frame *[now; 5 years; 10+ years]*?

The heterogeneity makes this question incredibly hard to answer.

Dr. Gray introduced the Cooperative Research Center (CRC) as an example of a large organization that performs team research. CRCs are formalized vehicles for fostering innovation and technology transfer, usually between industry and universities. They are immensely important to the U.S. “innovation system”, providing 70% of industry support for universities and representing 20%-25% of university research.

There are specific challenges facing CRCs as an example of team science, composed of a triple helix of collaborators (industry, university, and government collaboration), each of which has a different set of expectations and measures of effectiveness. The question becomes, How do you develop an evaluation approach to measure each of the stakeholders’ expectations? Evaluation is applied research to aid decision making; for CRCs, this includes sponsor agency oversight, and congress/sponsor agency/industry proof of efficacy and quality.

One missing stakeholder is the CRC management; while accountability is an important purpose for program evaluation, the application of evaluation results should be used to help managers improve the program. This has led to ***improvement-oriented evaluation***, with the purpose of improving the program while the evaluation is happening.

Dr. Gray described a multilevel evaluation strategy and used the NSF Industry/University CRC Program evaluation as an example. This CRC is the oldest consortium program in US, with only modest support from NSF and the bulk of funding coming from industry. NSF has made a commitment to integrate evaluation and improvement. To do this, each center has an embedded social scientist who is an objective evaluator and also an on-site consultant for the center. They use various methods and perform impact and outcome evaluations with the ultimate goal of improving the CRC.

The study found that many researchers are concerned about the unintended consequences of collaborations with industry in consortium models, in particular, the concept of the “kept” University, in which the collaboration with industry is eroding the quality of research and student training. However, there was no evidence of this based on the improvement-oriented evaluation. Dr. Gray’s group also asked, “What factors produce satisfaction and organizational commitment with team science? Faculty involvement is critical, but participation is voluntary, so what keeps them involved?” The leader is central: they must recognize the intrinsic rewards and satisfaction of working within a CRC. They also asked whether office and laboratory space affect collaboration and innovation. They looked at workplace layout and investment in the physical plant, and found that the better the space, the better the face-to-face contacts, the more innovative the outcomes.

There are many more studies going on or planned – including an evaluation of graduate student success and human capital leadership development as well as a pilot study of economic impact of CRCs. Dr. Gray summarize by saying that evaluation of CRCs is very difficult, with the need to match the methods used with the complexity of the multi-level model. They have to strive to balance evaluation for accountability with evaluation for improvement, to produce actionable information with which the evaluator can help the team run more effectively.

**Evaluating Team Science and Translational Science: The Challenge of Time**

*William Trochim, PhD, Cornell University*

*Director, Office for Research on Evaluation; Director of Evaluation, Weill Cornell Clinical and Translational Science Center; Director of Evaluation for Extension and Outreach*

Dr. Trochim introduced his presentation as a cautionary tale—he sees the translational research train and team science train entering the same tunnel from different directions, and wanted to share what he is worried about.

**The rise of translational science, history, drivers, and barriers**

The NIH established the CTSAs and there are currently 55 centers funded at approximately $500M/year. There are new journals dedicated to translational science, and in the Fall of 2011, there will be a new center at the NIH: the National Center for Advancing Translational Science. Translational science is big, and it’s here to stay. Dr. Trochim asked, “What’s driving it?” The fundamental rationale behind translational research is that it takes an average of 17 years to get research to clinical practice, and translation only happens for 14% of new scientific discoveries. Things are simply taking too long.

Translational research emerged in part to address this 17-year problem. Many definitions of translational research have emerged, and Dr. Trochim presented four of them: the Clinical Research Continuum (Sung et al., 2003) described the T1 (basic science to human studies) and T2 (human studies to clinical practice); this model was expanded by Westfall et al., in 2007 to include a T3 step, which further divided the T2 block into translation to patients (guidelines) and translation to day-to-day practice (implementation). There was also the insertion of reverse arrows along the continuum, suggesting that clinical information flows back to the bench. Dougherty and Conway in 2008 also developed a T3 model with the bidirectional arrows, and Khoury et al. (2007) introduced a T4 model. It is clear that over time we are adding more sub-phases to the translational models.

Dr. Trochim’s group performed a synthesis of these four models that is currently in press in *Clinical and Translational Science*. As evaluators, his group was concerned about the many steps and sub-steps in these models and whether they introduced cacophony for evaluation. They moved to process models, asking, “How long does it take to move along the continuum?” We can get very specific about each of the steps, and each segment can be broken out even further. By doing this, we can show more precisely where the process slows down. There is a lot of effort being done to evaluate the pathway, but the unmistakable conclusion is that translational science is largely about reducing the time.

**Current knowledge and key issues**

Preliminary findings on team science suggest that evaluation of team science requires longitudinal studies that extend over many years, as the efforts of multiple researchers are established and coordinated. Team research takes time!

**The conflict**

***The conflict is that translational science is largely about reducing time, but team science takes time.***

Dr. Trochim expressed the concern that there is a danger that evaluation of team science will show that it is *impeding* translational science. The challenge is one of a local versus global—or proximal versus distal—scale. In the short-term (local/proximal), team science will tend to increase the time it takes for translation, but in the long-term (global/distal), the hypothesis is that team science will reduce the time it takes for translation.

Team science enables interventions to be more robust in their construction and implementation (because of an interdisciplinary advantage), and team science enables research to anticipate problems and fix them earlier in the process. Without a distal “look ahead,” team science may be perceived as something that slows down translational science.

**Implications for the evaluation of team and translational science**

Dr. Trochim is afraid that the evaluators will be stuck in the middle. To avoid this, evaluators need to incorporate a comprehensive systems model of translation that spans the entire spectrum and recognize that not all research is comparable, not all teamwork is equal, and they must look at what a particular team is designed to do. As a cautionary note, SciTS advocates need to be aware of this potential challenge to team research, as a potential unintended negative consequence of team science.

**Panel Question and Answer Session**

**Q:** Is there evidence that community engagement in academic practice partnerships like CTSAs that involve clinicians will reduce bench-to-bedside time?

**A:** I do have hope that it will, but all these models of translational research show backward arrows and I am concerned about this. If we look ahead at the implications of team science, we might be able to reduce the cycles throughout he translational process and reduce overall time. It will be hard to evaluate and we’ll have to wait to get an answer. Team science in the short run might lengthen parts of the translational process.

**A:** Within the CTSAs, under the evaluation, there is a group that is looking at social network analysis (SNA). We’ve started 2 initiatives, but in the last month, we’ve looked into a SNA of CTSA engagement of the community. We’re helping various CTSAs put together social network instruments to look at various stakeholders, and we have about a dozen schools that have signed on. This is not only way, but it may be helpful.

**Q:** In Europe, they’ve had European Framework programs, some as large as 12 universities and across 5 countries. In the beginning, they had the same challenges, but were able to overcome them by instituting a project management core with systems, communication patterns, and external organizations that manage the project. Has any of these approaches been tried in the US?

**A:** One of the functions of the administrative core of the IRC is to manage those functions.

**A:** In Industry-University centers, some would argue that they’ve gone too far with developing a standard, strategy plan that is disseminated—a tool box of fairly standard things. The typical person who serves as an evaluator comes into a new center and has institutionalized expertise from having worked in another center. The evaluator can bring some of those best practices with them.

**Q:** What are your plans to use CIKnow to find collaborators between institutions rather than within a single institution?

**A:** We want to implement models that cross universities. We expect that one institution will do better because it has collaborations with other universities. The VIVO project is doing this and we are working with them on their RDF data and trying to use the tools to leverage their information.

**Q:** Evaluation of outcomes focus on the short-term, but how do we measure outcomes in the long-term, beyond those stated in NIH grants, beyond the number of grants and the amount of money?

**A:** It is really an issue of assessing the impact. Funding agencies are looking for the impact of the funded research. Some of the outcomes are visible and some are transfer events that lead to technology. If that happens in a firm, there’s no incentive for them to share because they want to capitalize on it.

**A:** Our society is not renowned for taking the long-term view. We’re already being asked to evaluate outcomes from CTSA—I fear there is going to be a challenge, that it is still taking too long. We must start educating people about this issue. We will be starting a series of retrospective case studies that look at successes and trace back the factors that drove the success. Until the centers are around long enough, SciTS may be in trouble and viewed as an obstacle.

**A:** We want to do translational science faster, but I wonder if there is a limit – maybe it’s not 17 years, maybe it’s 12 years. It’s good that you are looking back to see what worked. It would be more interesting to determine what factors let us do it well rather than what is holding us back.

**Q:** How much did it cost to set up CIKnow and did you conduct any evaluation of success of users of the program?

**A:** We kept the data from round 2, and then tested the model; it was a retrospective check of our model. We have not had researchers actually use the model yet. This was a research project that has been funded over a decade by NSF and NUCATS, but it has not been commercialized yet. There are other programs that are being developed commercially and some developed by specific universities that are being used.

**Q:** The SNA tool is only as effective as the data you have in your database. What databases have you mined?

**A:** We did not use any survey data, though we’re close to doing that. The data we do have is from NUCATS itself and the ScienceTicker from Thompson Reuters for co-citations out of Web of Science. This is not a trivial thing because you have to reconcile the data. Life is too short and you have to make decisions about who you want to collaborate with and a short time in which to do it.

**Q:** In your NSF study, was there a difference between disciplines?

**A:** No, but we only had access to the data for a very short period of time as part of an advisory subcommittee for NSF to find reviewers with conflict of interest issues. Because of limited access to their servers, I could not do any further analyses. That’s a great question though.

**Panel Session: Methodologies of SciTS Research**

The presented different methodologies to analyze research teams and their dynamics. One approach to studying scientific teams is to manipulate them and then assess the impact of the manipulation; another approach to study teams includes observing and analyzing their behaviors using a combined qualitative and quantitative approach. A mixed-methods approach is used to answer important questions about the formation of science teams and inform about various factors, such as composition of knowledge diversity and the team processes, which can support team efforts to innovate and advance scientific knowledge. Methodologies can address issues of science team leadership in relation to emergence, actions, and team impact. Network and large scale dataset analysis can be used to understand team cohesiveness and productivity at a microscopic level and how collaboration patterns can be linked to productivity at a macroscopic level.

**A Case Study – The Toolbox Project**

*Stephen Crowley, PhD, Boise State University*

*Assistant Professor, Philosophy*

Dr. Crowley started the session with a specific example of The Toolbox, which possesses common features that come up when looking at the practice of team science, and includes a technique/instrument of possible value to others.

**What was the initial problem?**

The NSF IGERT grant at the University of Idaho focuses on biodiversity and agriculture. Students develop research programs as teams and coauthor their dissertation chapters. One year into the program, the students felt substantial uncertainty about what they were meant to do.

The initial response was to “fix” the IGERT by improving communication between team members. If this approach was successful, it would confirm that hypothesis that communication was the issue while also fixing IGERT. We used the Toolbox, which is a structured, self-guided dialogue about team members’ philosophy of science rather than the particular details of their project or task. Dr. Crowley showed an excerpt of the survey used in the Toolbox.

There have been some challenges regarding measures of success, whether they are short- or long-term, or subjective or objective. Data analysis includes Likert scores, self-reports, and transcript analysis. Another question concerns the realm of applicability, or who gets “treated” based on the results. Do the finding affect non-research teams, and if so, then which ones?

**Methods for SciTS Research**

*Maritza Salazar, PhD, University of Central Florida*

*Research Associate, Institute for Simulation & Training (IST)*

Dr. Salazar is interested in what makes science teams more effective. The methods used to answer this question depend on the state of team science:

* Nascent theories can be tested with open-ended enquiry to ask what organizational change processes facilitate the use of science teams. Methods can include participation observation, semi-structured interviews, comparative case analysis, and archival documents analysis.
* Intermediate theories can be tested by proposing relationships between new and existing constructs to ask how knowledge composition and team collaborative experience affect science team innovativeness; again, we can use participation observation, semi-structured interviews, archival/organizational document analysis, and surveys.
* Mature theories can be tested using focused questions or hypotheses to ask what predicts participation in problem-focused science teams. Methods include surveys, experiments, and coded and quantified data analysis.

Dr. Salazar then shared her research context as an ***organizational ethnography***. A medical center that had experienced a slump in performance, was having a problem bringing in funds, and was in the middle of a hiring freeze. The medical center decided to institute team science, but the knowledge was stuck in silos, with a divide and conquer strategy within separate departments. The center promised that the most innovative teams would get funding and designation as a center of excellence. A total of 64 teams self-formed after the announcement, and in 8 or 9 months there was a process of selection that assessed the innovativeness and promise of the teams. Six teams were deemed winners.

Dr. Salazar’s group did a survey, and about half of the researchers decided to participate. There was a gender imbalance, but it the participants were representative across the length of careers. Associate professors and basic scientists were more likely to participate in teams, as were those with distinctive expertise and who had previous experience with cross-departmental collaboration. She concluded that there is something about our tenure structure that is keeping junior faculty from forming teams, and early education of physicians and translational scientists should include ways to work in an interdisciplinary fashion.

Dr. Salazar asked, “What is the right mix of talent and experience?” ***Knowledge stock heterogeneity*** refers to the complex constellation of task-relevant knowledge from team members’ work-based experience that is contextually relevant. Together, the amount of diversity in disciplinary knowledge, the type of professional training, and the area of research or practice leads to innovativeness.

She hypothesized that the overlap of knowledge diversity would affect team performance. In addition, the leader of each team and the leader-member collaborative ties hinder innovation. She looked at data from 64 team rosters and hand-coded the members’ CVs. She found that teams formed, but they weren’t as heterogeneous as they could be. From this research variables of innovativeness were developed and used to score each team: (1) lead to world-class academic medical center; (2) create scientific distinction; (3) enhance basic, translational, and clinical science; (4) Lead to multi-investigator collaborative science. They found that team size had a positive effect on innovativeness, possibly due to synergy and integrative capacity of diverse members. However, some moderate overlap of knowledge had a positive effect of innovativeness.

Dr. Salazar also found that past collaboration between the team leader and members decreased innovativeness. To further examine the impact of leader behaviors on innovativeness of science teams, she attended meetings, audiotaped the proceedings, and two independent coders analyzed the transcripts for certain communication acts (e.g., agreeing, clarifying, questioning, connecting, disagreeing, encouraging, shifting topics, interrupting, and suggesting). Of the leader behaviors coded, the communication acts of questioning, connecting, encouraging individual participation, shifting topics, and suggesting new ideas all had a positive impact on the innovativeness of the team.

Dr. Salazar concluded that we do not yet don’t know as a community about how teams form and what they need to look like to succeed. She used a mixture of qualitative and quantitative metrics and mixed methods to try to answer questions about the effectiveness and innovativeness of science teams.

**Methodologies for SciTS – How Leaders Influence Groups and Group Structure**

*Paul Hanges, PhD, University of Maryland*

*Associate Chair and Professor, Social, Decision, and Organizational Science*

Dr. Hanges described how his group has been studying team dynamics in a cross-cultural context, looking at shared mental models within teams and how they influence the group. He shared his new work on team research, which required him to take a slightly different perspective than he has been used to.

Teams are complex because they are composed of richly interconnected elements as members talk to each other various ways; and they are adaptive because they can change and learn from their own experiences. Social communities, businesses, and research teams change as a result of their success or failures.

Learning is observed the team-level of analysis, looking at the unit as a whole, as a living organism, and not as individual personalities. Dr. Hanges described how we can look at emergent behaviors, such as leadership, shared mental models, norms, climate, and culture. He stressed that leadership is not an individual trait, but a dyad between the leader and member. We can also look at self-organization of teams, which also change over time from a disorganized group to one that is more hierarchical.

Dr. Hanges described how current methods and analytic tools are problematic for studying dynamic phenomena, and may even hide or obscure the dynamics. We therefore have to change the way we conduct research of teams. Multiple observations are required—we cannot take a single snapshot and say we know what is going on. We need observational methodologies, using archival data and recordings of public conversations with consent. We need a time scale and assess teams at micro-, meso-, and macro- levels, with social network data collected weekly. The key is to make sure that the methods used and the time frame are appropriate for testing the specific theory.

Quantitative data can be collected in lab settings, using daily diaries, social network studies, quantitative measurements. But collecting data is not sufficient; we have to analyze it, and Dr. Hanges thinks that the Likert scale hinders us.

He described the mouse paradigm, in which people sit in front of the computer and indicate with the cursor where they believe the group falls on a continuum (such as low to high morale) on a micro-time level, allowing instantaneous assessment of longitudinal changes in a perception of the group phenomenon. By the time the measurement period is finished, there is a “movie” of how the theory or group process has evolved over time.

Dr. Hanges also described a study that tracked how multi-person stimulus behavior evolves over time. Specifically, he looked at the shift from a male to a female leader in a small decision making group. The impetus for this experiment was the observation that though the percentage of women in the workforce has increases, women remain underrepresented in upper-level management; previous studies have shown that women receive lower leadership ratings and gender information is automatically processed. For this experiment, they used nine videotaped vignettes showing a range of small groups with strong male leadership to a female leader based on ability. There were 119 participants, evenly divided by gender, and 4695 observations made per participant. Repeated measures were made of between subject factors (emerging leader gender, participant gender, experimenter gender) and a within subject factor (frequency of leadership behavior). Dr. Hanges showed the results from a single participant’s leadership rating, which showed no gender bias, but that the individual was unable to tolerate ambiguity and saw leadership in terms of black and white. Another participant’s ratings revealed a high gender bias, but the ability to tolerate ambiguity.

**Data Analysis – From Large Scale to Small Scale Datasets**

*Marta Sales-Pardo, PhD, Universitat Rovira i Virgili, Tarragona (Catalonia, Spain)*

*Associate Professor, Chemical Engineering, Escola Tecnica Superior d'Enginyeria Quimica and Northwestern University, Adjunct Professor, Chemical and Biological Engineering*

Dr. Sales-Pardo started her presentation with the acknowledgement that data can easily trick us, but it does not lie. There are two types of data: small-scale, high-resolution data about a few teams and large-scale, low-resolution information about a large number of teams or individuals. The kind of data determines what questions can be asked and the kinds of methods that can be used to answer these questions.

Dr. Sales-Pardo asked, “What can large-scale data explain? Can it be used to assess gender differences in collaboration patterns?” Her group had access to the complete publication records for active faulty in three departments at selected US universities (chemical engineering, ecology, and industrial engineering). After cleaning up the data, they observed a loss of women from the academic pipeline. This led to the question, “What does it take for women to persist in academia?” The data indicated that they were publishing in teams more often than men. Previous studies indicated that teams are able to produce more impactful work, which led to the next question: Do women publish more and better because they work in teams? Her group hypothesized that women should have a higher propensity to collaborate than men.

The analysis revealed that men and women faculty have the same number of co-authors, but this suggested that female faculty have a higher propensity to collaborate because there are fewer women that persist in the pipeline. They also found that homophily controls gender diversity within teams, with men collaborating with men, and women with women. Because men tend to collaborate with other men, women need to be more collaborative within a smaller pool of potential collaborators.

Dr. Sales-Pardo then asked what can be assessed with small-scale data; specifically, can it be used to assess what it takes to be a good scientific team? Teams are independent and motivated to perform well for their own benefit. Her group obtained data through surveys of students working in teams. They assessed the goodness of structure using SNA methods, predicted the polarization within the network structure using dynamic modeling, and detected weak links within the network using complex network analysis methods.

**Panel Question and Answer Session**

**Q:** Did you use pre- or debriefing within the Toolbox questionnaire?

**A:** The teams we’ve worked with have been grad students and undergrad summer researchers, and in any sort of teams from all population backgrounds. There is a debrief that focuses on people’s experiences, but we don’t go out of our way to explain what we mean by the questions, because we don’t want to interfere. We use open-ended and ambiguous statements that challenge the team to define a term themselves by coming to a consensus as they move forward in the collaboration.

**Q:** There was a lot of talk about gender differences in leadership and formation of teams, but did you look at ethnicity or race?

**A:** We have not looked at it, but it’s an interesting question. Gender is the strongest effect, but it might be affected by ethnicity.

**A:** In my CVs, I didn’t code for race/ethnicity, but there is no way to tell. On qualitative interview tapes, I do have that information. We have been looking at things cross-culturally, and I want to mine that data for race/ethnicity. There are major behaviors that occur in response to race.

**A:** We chose gender, but we could follow up with race. The race of the participants was not examined in the analysis because we wanted a match based on gender.

**Q:** What about discipline-based homophily?

**A:** We saw that people who do internal medicine are more likely to collaborate, maybe because they are seeing the body as a whole rather than a specialized part. Every discipline has a tendency toward certain problems.

**Q:** You looked at 64 teams and their characteristics, did they include surgeons?

**A:** Yes, they did. There was something that unified bench scientists and surgeons in particular. We could join the physical and social sciences for moving SciTS forward if we could merge the native methods for leadership and team building and our models that we have tested.

**Q:** What do you mean by metaphysics in the Toolbox?

**A:** We wanted them to focus on what they did to get a result. What brings them to a collaboration, what brings them there. We also wanted to understand what they thought their product was and the relation of that product to the world.

**Panel Session: Barriers to Studying Teams/Effective Practices for Studying Teams Science**

In this session, the panelists focused on the logistical, theoretical, and methodological issues in conducting social and behavioral research studies of science teams. The panelists articulated potential challenges and how they have learned to overcome them. Using the input and wisdom of audience members and the experience of panel members, this session illuminated ways to optimize both the study of team science and team science itself.

**Practical and Theoretical Challenges to Study Team Science**

*Joann Keyton, PhD, North Carolina State University*

*Professor, Communication*

Dr. Keyton began with a question: How do you know whether a team is successful or effective? The traditional answers are publications, funding, a marketed product, and student training and placement. Science teams are teams, and the biggest challenge is getting in to study them and determine how scientists work together to produce these outputs. The black box in the middle is what happens between the team and the outcomes. For example, what is the impact of task of funding uncertainty on team performance, what is the impact of choosing versus being assigned to a team on the performance of individual members and the team as a whole, how does team training occur, and what are the most effective processes for sharing information and managing disagreement?

To study science teams, there are issues of gaining access, problems observing science teams in the field, and difficulties linking archival to behavioral data. With regard to gaining access, many science team members have specific concerns, like: What will you do to us? Who will know what we do? Will you publish information about us? Will you tell others about our research findings? Will you tell my PI? and Why do I have to sign a consent form? Dr. Keyton has to reassure teams that she is not interested in the science, but in the team itself.

Identifying who is in the team can be complicated due to fluid team membership— sometimes the formal team roster doesn’t match the actual team in practice. It can also be challenging to track physical and virtual team meetings, email and phone conversations, and individual work on team tasks versus team interaction on tasks. There are new technologies that are facilitating the collection of data on these team member interactions.

Finally, connecting administrative records collected by the PI or center administration to actual facts on the ground, and connecting team members to publications or tracking the life cycle of team members can be difficult.

Social and behavioral scientists can help science teams make better use of their resources, but they have to be invited in and they have to be invited in at the ***beginning*** of the process.

**Doing Interdisciplinary Research on Interdisciplinary Teams Research**

*Maura Borrego, PhD, Virginia Tech University*

*Associate Professor, College of Engineering*

Dr. Borrego mused that even though we’re stepping back and studying teams, some of the things we are learning are things we may need to implement ourselves. SciTS is an interdisciplinary field in and of itself, with a mix of perspectives, methodologies, and procedures, and all the attendees have come to this meeting to share.

The challenge is that it is difficult to find all this information, with no clear path to publication, different standards for publication, different audiences (i.e., practitioners of team science vs. researchers of team science), and the communities are scattered.

SciTS researchers must design their own studies for publication success and impact. They must determine what is practical and accessible for data collection, what audience to impact, what evidence is convincing or compelling, what theories or methods are expected and appropriate, and how success or impact is defined.

Dr. Borrego admitted that it can be difficult to define a successful or effective team. It is not always possible to tell who will be successful at the end of a longitudinal study. There are “objective” criteria for arguing that the team knows how to do things and qualitative, small studies are risky because it puts all eggs in one basket. It may be more revealing to spend time with a smaller number of teams who may not be successful.

Another challenge is in locating and recruiting teams. As an alternative, Dr. Borrego suggested that SciTS researchers may be better off cultivating themselves as a network node rather than focus on recruiting specific teams. SciTS researchers can position themselves as a value-added source and let the teams come to them for help. The relationship between the SciTS research and the team being researched can be mutually beneficial. What will the studied team get in return? Feedback for improvement, ability to check a box that evaluation is being done, flattery that they are worthy of study, and the opportunity for co-authorship about their program or intervention. A conference paper or journal article could be offered as a deliverable to their team.

Dr. Borrego finished with some practical advice on impacting practitioners of team science. She reiterated the need to cultivate a network of consumers, by sending preprints, setting up a Web site or blog, and attending events for their networking potential. SciTS researchers can also target practitioner publications and conferences, and explore workshops and other dissemination mechanisms.

**Practical and Theoretical Challenges to Studying Team Science**

*Paul Goodman, PhD, Carnegie Mellon University*

*Professor of Organizational Psychology*

The major obstacles to studying teams are temporal issues; levels of analysis; and criterion problems.

With respect to temporal issues, studying a team can be difficult not only because teams operate over long periods of time, but also because researchers come and go, critical decisions are made early in team formation, there are unanticipated events, and there are long lag times in effectiveness indicators. To address these temporal issues, SciTS researchers must collect lagged data, look at critical decisions, especially early ones (such as how a team frames problems, pre-proposal strategies, etc.), and do intensive longitudinal studies with real-time monitoring. Dr. Goodman recently studied a group in which they had access to every email and every Skype conversation. SciTS must have flexible instruments that let us go in and measure changes as they happen.

There are also obstacles posed by the fact that science team research occurs on multiple levels: individual, dyad, team, center, consortia, etc. The theory needs to identify and distinguish between appropriate levels and measurement and data analysis needs to match the theory. This gets violated a lot, with the wrong tools being used to measure a particular level of analysis. To overcome these issues, there needs to be good conceptual clarity that is built upon a well-developed research question and an understanding of the state of the literature. The literature doesn’t make a very good distinction between the levels, however. The key is to match theory, measurement, and analysis.

The third obstacle to researching teams is defining effectiveness. What criteria should be used? There are long lag times to publications, different constituencies have different weights and criteria for successful outcomes, and sample variation is limited to funded projects. SciTS researchers must identify alternative indicators of team effectiveness, and distinguish between intermediate and final criteria. Consider whether the team continues to work together as a measure of success. Final criteria are papers and funding, but intermediate outcomes that can be measured include things like formation of group identity and the capacity for group learning.

**Panel Question and Answer Session**

**Q:** What about teams beyond a particular project? When do teams become institutions and should they, or should they evolve and change? Is the mission larger than the team or the project?

**A:** It’s a really great question – I would look at those things, but the SciTS field is way off there because the teams are on 5-year funding cycles. Some do become institutions and if they don’t, their products may.

**A:** Centers can be institutionalized and dynamic but I don’t see it as much about teams working on a project. The institution always needs to innovate, but that’s different from teams.

**Q:** How important is it for someone who studies teams to understand what is being studied? I need to spend time understanding what the team is doing before I can study the team itself.

**A:** You don’t know what the team is doing, but you figure it out over time. As you sit in with the team, you almost become part of the team.

**Q:** But don’t I need to have some understanding of what they are studying, or is that asking too much?

**A:** Sure, but you don’t have to have a PhD in that field. We have to be knowledgeable enough to know what the outcomes are, but we want to be naïve enough to study it as an objective observer. Short tutorials and Web sites give some understanding, but we don’t have to have the same level of understanding as those on the actual team.

**Q:** As one attempts to assess team development and success, we rely on individuals filling out forms and surveys on what they think. How do you check and validate the answers against actual data on the team? Is it objective or subjectively gathered information?

**A:** One theme throughout the presentations is that there are multiple methods and it is virtually impossible to give people surveys that don’t prime them. We also need observational data, archival data. Using multiple methods is a fundamental way of doing this work.

**A:** Interaction data is really important. I have interactions between people, track messages between them, and quantify the interactions. Interaction data is the workhorse, but it also makes it really difficult because you have to convince them to let you track the interactions. So mixed methods data are the best.

**Q:** What is the size for group analysis?

**A:** If you want to do any kind of analysis, you need large numbers so you can do systematic analyses, but it’s really dependent on what you want to understand.

**Q:** Can you have an outcome that is achieved by individual members but not by the team?

**A:** Sharing of information becomes a major factor. You can have individual learning but not team learning.

**Q:** What about action research versus research. Do your findings feedback?

**A:** It depends on the relationship that you negotiate with the center. Sometimes my work end in a summative report, other times it a summative and formative report. My preference is to do action research so that the findings go back to improve the team.

**Q:** Going from situations like a laboratory, where there are different projects with no central focus, up to teams with a centered mission, are there different challenges to data collection?

**A:** I haven’t done those types of research, but my gut is saying there is no difference in the challenges involved.

**Q:** What are some practical steps to engaging the federal government for team science?

**A:** Scientists and engineers have a lot of money to do this type of research, going along for the ride as an evaluation person.

**A:** There isn’t a lot of money for this kind of research. With all the social science data, it’s been surprising that there isn’t any discussion of what levers can be pushed to incentivize this team science research. Case by case studies don’t seem as productive particularly because the teams are so short lived. Is there a better way to study this? How do you enable best practices for team science rather than just studying team science? How do you put your research into practice? These are provocative praxis questions.

**Q:** The teams are not that transient – the turnover is the grad students, but even those are a 6-7 year time horizon, and the PIs are amazingly stable. We are looking at 12 different centers – is that too small for social science study?

**Q:** Graduate training does not teach us how to run a lab, manage projects, or be a team leader. How should we change graduate school training to include team research?

**A:** Certain programs do include it, but not many. If they do, it’s about public speaking. I don’t know the reasons behind pushback on this issue—perhaps the curriculum is already so packed, they don’t know how to fit team science in?

**A:** Changing curriculum is always a little political, but in science and technology centers (STCs), the students always think that the training in interdisciplinary research is helpful.

**A:** Most grad students don’t know what they don’t know. We need to decide what needs to be taught before we change the curriculum.

**Q:** Have we done a good job of market analysis of our clients who would benefit from our work and data on their team? What do institutions give to teams regarding support for implementing good team practice? What are the central network nodes, who can come in and train on team science, what are the measures of finding people who desperately need team training? How do we get people to recognize they need help? How do we market what we have to offer, making it more attractive and exciting and worthwhile to those who need it?

**A:** Folks are so driven by funding that unless evaluation is built in as a funding requirement, they won’t do it. We can’t market it enough. I’ve tried to show the value added, but if the funder doesn’t require it, they won’t do it, even if they do see the potential value. It’s an interesting challenge.

**Q:** Does project management methodology have any impact on team science?

**A:** I understand the focus on training. In certain areas we know a lot and it can be applied to science teams, but there are unique features of science teams that you can’t just plug in team training from other groups. We need to be careful about focusing on training when we don’t know everything there is to know about teams.

**Panel Session: Antecedent Conditions Necessary for Effective Team Science**

This panel included an overview of the history of cross-disciplinarily and the barriers posed by current institutional structures and policies of tenure. The panel also addressed how researchers engaged in collaborative team science define transdisciplinary research and their perspectives on transdisciplinary processes and outcomes, as well as how cross-disciplinary research orientation relates to researchers’ collaboration networks. The panel concluded by suggesting core principles and implications for studying transdisciplinary research.

**Cross-Disciplinarity: Old and New Problems and Perspectives**

*Frank Kessel, PhD, University of New Mexico*

*Senior Fellow in the Robert Wood Johnson Foundation Center for Health Policy and Professor of Early Childhood Multicultural Education*

Dr. Kessel conveyed regrets from his co-presenter, Patricia Rosenfield, who could not come to the conference, as much of what he presented was stimulated by her current project writing the centennial history of the Carnegie Corporation.

Dr. Kessel’s perspective is as a commentator who attempts to analyze the process, and the acceptance and promotion of the process, of conducting inter/transdisciplinary [ID/TD] research (used synonymously with “team science”), particularly across the health and social sciences. Drawing on recent and current case studies, and complementing the work of many others, he discussed the range of factors that facilitate and constrain ID/TD research. More recently, he has begun to examine past efforts—notably by U.S. foundations—to foster interdisciplinary research. Against that background, Dr. Kessel sketched what seems to be the current “Golden Age” of ID/TD research, point to a previous “Golden Age” as a cautionary tale, and suggest how a fine-grained analysis of that historical story might bear on current and future challenges.

**Perspectives on the Golden Present – All to the Good?**

There have been some recent signs/symbols that this might be a golden age of ID/TD research, including educational research, the new-ish NSF FIRE program funding team science, increased NIH funding, and SCRD presentations on child development research needing interdisciplinary approaches, and the need for building bridges between economics and child development research. There is also an ever-expanding interest in studying and facilitating cross-disciplinary collaboration, with several books and journals emerging.

Dr. Kessel asked, “How Golden is team science? What is gained and what is lost when disciplines merge?”

**Perspectives on the Golden Past – Lost Currency?**

The previous Golden Age occurred in the mid-1920s, and Dr. Kessel shared a policy statement made by the Social Science Research Council that introduced five interlocking principles of social science, one of which was that it is a collective enterprise. In addition, Rockefeller philanthropies pushed for interdisciplinary coordination and the Carnegie Corporation gave money for fellowships for research at the intersection of several “-ologies.” The 1940-1960s were the high point in interdisciplinary research, but there was tension within the corporate structure in keeping the teams together. Dr. Kessel shared a quote from William Sewell quote on the 4 major reasons that teams failed in the first Golden Age of team research: (1) they posed a threat to traditional university department structure, (2) they lacked appropriate support, (3) there was a lack of major breakthroughs, and (4) the research methods did not greatly increase understanding.

**Persistent Challenges in Light of the Past – for the Present and Future**

The same problems exist today, even with ringing rhetoric to initiate and sustain TD/ID research, and many initiatives die. Dr. Kessel asked, “Are we heading down a similar path?” This is not unlikely if only because of severe budget pressures that have led to cuts rather than ID/TD restructuring of institutional units, curricula, and tenure policies.

The research praxis challenge is that imaginative approaches are needed for team building, including ways to engage users of research in the conduct of research, especially across cultural divides. One conceptual solution is ***heterarchy***, a framework for analyzing multi-level, multi-layer problems, and an approach for addressing, structuring, and developing teams drawn from a wide range of fields and institutions.

One challenge to the implementation of an ID/TD paradigm is that there is still a need to build a body of assessed knowledge and practice that illustrates how ID/TD research is more effective than research as usual. There is a need for results that could persuade policy-makers and/or the public to provide support for the ID/TD research process, including sustained support within academic institutions. In particular, what lessons can be learned from Sewell's ID failure story and Woese's concern about reductionism and loss of broader systems perspective? One potential conceptual solution is ***panarchy***, a framework and approach to building dynamic connections across heterarchical teams and user communities for critical assessment of work and effectiveness of results across a variety of settings. There is one corollary: building an accessible knowledge-and-practice base so that students can become comfortably “acculturated” into the ID/TD paradigm.

Dr. Kessel is convinced that viewing various facets of the scientific/scholarly landscape through a heterarchical lens has significant heuristic power. Researchers are demonstrating that understanding the rich complexities of human health is most likely to emerge via work that recognizes and embraces, in theory and research practice, multiple levels of analysis (and the associated principles of multiple, non-additive, and reciprocal determinism).

In the context of organizing crossdisciplinary research, heterarchy’s beauty is the way it provides for the legitimate valuation of multiple types of knowledge, or working styles, or approaches, or methods, without privileging one over the other. Put somewhat differently, the more interesting non-hierarchical question is “Which types of research approaches and methods are most appropriate to address which questions, and in a transdisciplinary spirit, how can they be made creatively and, yes, heterarchically complementary?

With networks, and networks-of-networks, in mind, what if norms and goals are not shared? A central theme in ID/TD literature is how to create time and space that will/might enable engaged agreement on goals and norms across disciplinary boundaries. The issue is even more complicated in the context of implementing or translating research.

The possible next steps should bear in mind cultural differences/divides of various kinds, and it will be invaluable to continue to foster a series of complementary conversations along several intersecting dimensions. This includes conversations between scientists attempting to sustain boundary-crossing research and scholars elucidating the concepts of both heterarchy and panarchy. It also includes discussion between this SciTS network, those engaged in td-net, and the funding agencies. Moreover, these conversations should include contributions from a range of constituencies of research “users” and those who know about the history of earlier ID/TD initiatives.

**Conclusion – Back to the Future**

Dr. Kessel concluded by asking what might a crucial historical perspective on ID/TD research provide? Why do we believe that our current cross-boundary efforts are likely to be more institutionally sustainable than those in the 1920s through the 1940s? More specifically, will the fact that the current “Golden Age” is fueled by more Federal agencies (rather than foundations) make a difference? The conceptual frameworks and analytical tools we use would be significantly sharpened if they were brought into reciprocal contact with the grindstone of history. We need to honor those who came before us by learning from their experiences.

**Where the Mantra Meets the Mismatched Metric: Tenure and Promotion in ID Careers**

*Julie Thompson Klein, PhD, Wayne State University*

*Professor of Humanities, Interdisciplinary Studies Program*

Dr. Thomson Klein discussed the gap between rhetoric and reality with regard to interdisciplinarity. There are several things that impede ID research, and they tend to accumulate disadvantage, including promotion criteria, budget control, strategic plans, space, and unit reporting.

There are guidelines and criteria that are coming into place, but there are still issues with changing institutional and committee structure and culture, and with regard to tenure dossier preparation. Changing a curriculum is as difficult as moving a graveyard.

Cathryn Lyall’s book, *Interdisciplinary Research Journeys: Practical Strategies for Capturing Creativity*, shows that researchers become increasingly interdisciplinary as they move through their careers. The book provides recommendations for taking charge and nurturing an ID researcher’s career pathway. Another question has to do with graduate student training – how do they negotiate a career path when they are doing ID work? It is important to think about careers strategically – how and when to get involved in ID, and how to present ID work in the tenure process.

Each institution will have a different emphasis or support for ID research. During hiring and pre-tenure review, committees must be educated on ID research and its value and there must be a way to annotate the CV to indicate ID involvement.

The candidate needs to be able to articulate the value of ID research and the reasons for doing it in terms of their particular discipline. They need to gather evidence, anticipate impacts on the field, and on the candidate’s career trajectories.

What do you do about collaborators who are not co-PIs? The NIH ombudsman’s site gives some guidance on how to track this and document the tenure candidate’s role on team. Who is responsible? The orphaned or neglected candidate, supervisors and mentors, individual ID units, professional organizations and networks, or local institutions?

There is a lot being said about ID research, but we need graduate-level interdisciplinary learning outcomes to be able to articulate the actual value of ID research to change tenure policies.

**Transdisciplinary Definitions, Perspectives, and Principles**

*Kara Hall, PhD, National Institutes of Health, Program Officer,*

*National Cancer Institute, Division of Cancer Control and Population Sciences, Behavioral Research Program*

In order to motivate agencies with evidence that there is value in interdisciplinary/transdisciplinary research, Dr. Hall presented several overarching questions that need to be answered: How do we define transdisciplinarity, why do we need transdisciplinary science today? How do others define transdisciplinary research, and what are some principles of transdisciplinary research?

There is a continuum ranging from with unidisciplinary to cross-disciplinary forms of collaboration. Transdisciplinary research is truly integrative, as a process in which research work jointly to develop and use a shared conceptual framework that synthesizes and extends discipline-specific theories, concepts, methods, or all three to create new models and language to address a common research problem. This is contrasted with multidisciplinary, which is a sequential process, and interdisciplinary, which is an interactive process.

In our social and scientific world, we are asking more complex questions as science becomes more complex. We are in the midst of a knowledge, data, and technology deluge that is continuing the evolutionary need for TD science.

There has been an exponential increase in publications, disciplines, fields, and subspecialties and there has been an increase in new ideas and challenges. Due to increases in publication and access to publication there has been a decrease in simultaneous discovery, and the silo-ed nature of advancement continues because of the deep and narrow knowledge that is necessary. However, there are more ways that we can potentially integrate and encourage cross talk between those with specialized knowledge.

Technology has increased production and access to knowledge and data, and is allowing for continuous measurement in real time. There is a huge amount of data to process and understand. But we also need to go beyond the data; there is the concept of social participation in data collection (crowd-sourcing) that further increases the volume of data.

What does this data deluge mean? We need integration within and across areas to reduce duplicative efforts, advance science by leveraging the best across areas, and account for multiple levels of analysis. To achieve this integration, we need scientific infrastructure, including computing and analysis capacity;, data sharing and grid computing; and new methods, approaches, and conceptual frameworks. All of this has led not only to the complexity of science and knowledge, but to the complexity of collaborations and how science is done.

Transdisciplinary science is essential, but we continue to struggle due to complexity of context. We need to have an evidence base to prove that transdisciplinary science is worth the struggle and to establish the need for support. We need an evidence base to understand and deal with complexities of transdisciplinary science, and to enable scientists to do this kind of science more effectively and efficiently. As Dr. Eduardo Salas described in his keynote, we need to understand the phenomenon, know how to capture it, and know what to do about it.

First thing we face is a problem with the definition of transdisciplinarity itself; we don’t know what it means when we are applying for a grant. NIH has no formal definition, and nearly all mentions of transdisciplinary research are in FOAs issued by NCI. We are using this term over and over again but not defining it (rhetoric versus reality).

The NAS and NSF do a better job of defining it, and there are even more definitions in the literature base, in particular, from Klein in 2010: there is Multi, Inter, Transdisciplinary research that lies along a continuum of auxiliary, supplementary, and structural interdisciplinarity and integration. Fully transdisciplinary research is transcending and transforming.

But how are researchers defining transdisciplinarity? Do they see it as a process or an outcome? Dr. Hall performed a conference survey to learn how scientists who are already engaged in or are interested in cross-disciplinary science define transdisciplinary research and understand the roles of research process and outcomes in transdisciplinary research. She wanted to explore whether there are differences in how transdisciplinary research is defined by scientists who are or are not engaged in a transdisciplinary research center grant (TREC).

Dr. Hall presented the results of the survey. The scientists conceptualized transdisciplinary as a process rather than as a research outcome, and defined it as drawing form the methods, perspectives, concepts, and theories of multiple fields or disciplines to address multiple levels of science and that is conducted with a team of diverse colleagues. Challenges identified included the politics of convening a team, coordination of activities among team members, language barriers, the risk of compromising personal research objectives, the time consuming nature of collaboration, and the existence of disincentives to engage in transdisciplinary research. The benefits included teamwork and the ability to broaden experience by collaborating across disciplines. The surveyed scientists focused on the benefits, describing transdisciplinary findings as more comprehensive, providing a better big picture view, as having more relevance to more disciplines, and better able to produce novel findings. Scientists who were already participating in an NIH-supported center grant that provides support for collaboration were less likely to identify challenges, suggesting that the center structure, including the coordination center, is reducing barriers and providing support, tools, and incentives. It also indicates that those who endorse transdisciplinary research tend to be brokers in the network.

Dr. Hall then introduced the Team Science toolkit from NCI. The toolkit is an online tool that helps investigators find and share resources that support the practice and study of team science. It facilitates information and knowledge exchange via a wiki-based platform, users can freely upload/download publicly available team science resources, and the tool helps reduce replication of resources and accelerate advances in the field.

We must first agree on definitions so that we can generate guidelines and guidance for evaluators (to study processes and outcomes), grantees (to conduce transdisciplinary research), program staff (to develop funding to support transdisciplinary research), and funding agencies (to develop review criteria and enhance evaluation of transdisciplinary team science). The framework of these principles will be multi-level, represent cross-cutting and emergent states, and take into account multiple sequential phases of research that are cyclical and iterative. There are unique characteristics within each research phase that should be assessed and for which guidance is needed.

**Panel Question and Answer Session**

**Q:** Do you have advice for talking about definitions when you are out in the field giving talks? Is there a preference for certain terms? I have experienced some pushback on the definitions.

**A:** As a group, we defaulted to cross-disciplinary to encompass all of the definitions. The reality is that people who just want to do good research may not need to know the precise definitions.

**A:** Thumbnail definitions that are authoritative are good in the beginning, but nuances are not necessary. It might be best to start simple and elaborate as needed.

**A:** I’d ground it in the work being discussed and put the definitions at the end as a discussion point.

**Q:** Can you muse on two explanatory rationales on why the golden age didn’t go forward, and how it relates to the lack of commonality of perspectives across anthropology, sociology, and psychology versus the inability to solve complex social problems?

**A:** Both. It may be difficult to work across disciplines that are already pluralistic. But the other side is important too. We hope that the social problems are still there to be solved – we want to believe that putting our heads together will get us closer to the solutions than working alone. It is dependent on the inertia of the institution as well – it is very hard to get people to accept different types of definitions and criteria for teamwork. I took to heart what Julie said about moving graveyards; but I think we stand a much better chance now to find solutions, though we still need to get around the institutional pressures and policy obstacles.

**A:** Our academic institutions are run by folks with interdisciplinary orientation and who bring their biases to the table; they may not be willing to support interdisciplinary/transdisciplinary research.

**Q:** How much of this is a funding issue? I have a philosopher and a sociologist working on HIV to create a new framework to stop the spread of HIV. How are they going to be evaluated by the agencies if it is totally new? All of the views need a time of trial and error – perhaps this combination is not going to work, but we need funding to try it.

**A:** In the NIH, one of the challenges is that there is a difference between funding and review, with review being done by peers. I’m always trying to get people involved in the review process – but if peers aren’t reviewing these proposals in an open-minded way, they may not be funded.

**A:** Other institutions/foundations may be more flexible to funding these projects than the NIH. The classical evaluation criteria may be infecting the foundations, but they value creativity to a greater extent than the NIH.

**A:** There are new mechanisms that use special “on-the-fly” reviewers when a topic is unconventional.

**Q:** Regarding the usefulness of definitions, in a teaching and training context where we’re trying to teach students to think in this transformative way, transdisciplinary provides a goalpost for transformative transcendent research while staying grounded in their particular discipline. What are some of the educational strategies we need to take with regard to transdisciplinary research? There is an aspirational function to the continuum and in terms of the outcomes that emerge from that continuum.

**Q:** What is your personal experience in making changes to reduce the accumulation of disadvantages and what would the first step be?

**A:** It really depends on the institution and their culture. Certain schools are more open to transdisciplinary research than others. It is important to go in and examine criteria and expand them in a way that is informed by models or examples from other institutions. The dean plays a very pivotal role in this process.

**A:** This was the impetus for the NCI Toolkit so that others could see what other institutions are doing and help stimulate change in their own institution.

**A: T**his didn’t exist in the 20s and 40s partly because it was a small club and they thought they could change the world with the funding they had at their disposal. But power is much more dispersed now with a much greater chance of success.

**Q:** How do you get models out there to the faculty in order to change the culture at their institution?

**Q:** Even now, when we raise the fundamental questions we tend to fall short. We need a philosophy of transdisciplinarity.

**A:** I love the idea of a philosophy of team science; I always said we need to have an Art of team science before we have a science of team science. We need to agree on the problem rather than the definition. What are the problems, are they defined by the disciplines? If so, then we won’t be able to get out of this track. If the problems are coming from somewhere else, then the odds are better that folks from different places can come together to solve the problems.

**Panel Session: Collaboration Readiness and Conflict Resolution in Teams**

The panel examined collaboration readiness and conflict across affective, behavioral, and cognitive levels. They addressed theoretical and practical issues associated with the dimensions of collaboration un-readiness and readiness and conflict development and conflict resolution. By understanding both the intra- and the inter-personal aspects of teamwork, it will be possible to identify the most effective steps for embarking on collaborative work and how to address conflict when it arises in team science.

**Introduction**

*Stephen M. Fiore, PhD, University of Central Florida*

*Associate Professor, Cognitive Sciences, Department of Philosophy, Director, Cognitive Sciences Laboratory, IST*

Dr. Fiore opened the panel session with some thoughts on conflict and collaboration and why they need to be discussed in the context of team science.

**The Past – Why Conflict and Collaboration Etymology**

Dr. Fiore explained that the etymology of “conflict” dates back to the 1400s in the context of battle, whereas that of “collaboration” starts in the mid-1800s with origins in literature and art. He showed a Google Ngram—a graph of the frequency of words in all digitized books—that illustrates that since 1850, the use of the word conflict has increased much faster than the word collaboration. Once the word collaboration began being used in the context of work, the word conflict changed from one describing war to one that describes a clashing of ideas.

Dr. Fiore shared the famous quote from F. Scott Fitzgerald: “The test of a first rate intelligence is the ability to hold two opposed ideas in the mind at the same time, ad still retain the ability to function.” He stated that this ability is what is needed in team science, because conflict naturally emerges as ideas evolve from the collaboration.

**The Present – Why a Panel of Conflict and Collaboration?**

Dr. Fiore shared the “tortoise shell” map of a research agenda for team science that was developed at the 1st SciTS conference (now in press in Research Evaluation). It identifies broad research areas of team science with the goal to help SciTS move forward at theoretical, empirical, and translational levels. Dr. Fiore explained that we can’t study the entire map, the panel discussion focused on the “Nuts and Bolts” part of the map, looking at the characteristics and dynamics of teams, including collaborative readiness, the types of conflicts that arise, the development of trust, and communication styles, among others. However, these things cannot be studied in isolation, and the panel was convened to discuss different facets of the interconnections between dynamics, context, and institutional support of collaboration and conflict.

**The Future**

Dr. Fiore listed some questions for discussion:

* How do we account for the multifaceted nature of constructs for collaboration, including trust, cohesion, and conflict?
* How do we develop models describing the complex interdependencies among these attitudes with in science teams?

**Collaboration Readiness and Conflict Resolution in Teams**

*Michelle Bennett, PhD, National Institutes of Health (NIH), National Cancer Institute (NCI)*

Dr. Bennett works with Howard Gadlin, the NIH ombudsman on the practice of team science. She started her presentation by asking, “What is a scientific research team?” She proposed that we think of it as a continuum, from investigator-initiated research to research collaboration, to an integrated research team. Successful research teams can be initiated from the top down or bottom up, but there has to be support from the top.

Doing team science successfully is actually dependent on many things: process, trust, institutional support, communication, funding, sharing credit and resources, and power. ***The goal is to contain conflict but also foster disagreement*** so that all ideas can be heard, discussed, and come together in new ways.

In practice, many elements must come together: trust, membership, shared vision, getting and sharing credit, conflict resolution, adversarial collaborations, communication and negotiation, team dynamics, team networks and surrounding systems, challenges to the success of scientific teams, fun, and leadership. All of these elements are included in the NIH Field Guide, which can be helpful for leaders of team science who must define, teach, and use common language with team members.

Translating knowledge about what is needed in teams to action in the day-to-day work of teams, such as in development of the team leader, moves from unconscious incompetence to unconscious competence. We move from “we don’t know what we don’t know” to “we know what we don’t know,” and then we learn how to fill the gaps in our knowledge to achieve conscious competence. At this point, we start to use the skills learned and then once those skills are ingrained, we’ve reached a state of unconscious competence, when we start to model these skills to the next generation of researchers.

As an individual moves from self to group identity—away from status/ego, power/control, and autonomy to high integration/interaction and multiple interdependent leaders—he or she is moving from independence to INTERdependence.

In the Model of Team Development, Bruce Tuckman described the “Storming” stage, when power, status, and autonomy are threatened, and there are challenges in creating trust, understanding personalities, style, language, culture, and status in the group. This leads to conflict, but by giving this period the active label of “Storming,” it allows the team to recognize what is happening and empowers them to work through it.

All of the change points in a scientist’s career are about establishing independence: preparing to enter the workforce, competing for that first position, and tenure decisions. But Dr. Bennett reminded the group that scientists are doing their best work when they are younger. There is a disconnect: where young scientists doing their best work are supposed to establish independence, and participating in team science is risky and usually taken on by more established researchers. The question is how to make team science less risky. The institutes want researchers to collaborate, but the university says wait until after tenure. Dr. Bennett proposed the use of collaborative agreements—a explicit, structured set of questions that a group will answer in the early stages of the collaboration—as a way to provide a scaffold for trust and reduce risk. Without trust, the team will not be able to work off each other.

Dr. Bennett also shared a template for tenure track offer letters that gives researchers a way to include their participation in or leadership of an interdisciplinary research project in the offer letter.

**Collaboration Readiness and its Role in Success**

*Gary Olson, PhD, University of California-Irvine*

*Professor of Information and Computer Sciences*

Dr. Olson introduced the concept of a ***collaboratory***—a laboratory without walls, where virtual team science takes place. Collaboratories are fully distributed geographically. Using a broad empirical and theoretical approach, the science of collaboratories can help distinguish successful from unsuccessful approaches to virtual team science projects. Much of this work has been published in his book, *Scientific Collaboration on the Internet* (2008).

What is a successful collaboratory? One that impacts the science itself, science careers, and science education; is an inspiration to others and changes public perception; and allows reuse of collaborator tools.

***Collaboration readiness***: the community has to have a spirit of collaboration, a motivation to work together, bringing a mix of skills, with a feeling of greater productivity because the team likes working together, and that there is something in it for everyone. When this is missing, it is one of the biggest reasons for failure of a virtual team. Collaboration readiness can be measured in terms of trust, alignment of goals, and group self-efficacy. A problematic issue for virtual teams is when it forms as a mandate from the funder, as a requirement to be funded.

There are claims that collaboration readiness is necessary but not sufficient for success of virtual teams. Dr. Olson shared several examples of teams to demonstrate how importance collaboration readiness is:

UARC is a Greenland facility to gather research data. It shows very high collaboration readiness, with a long tradition, a Rules of the Road, and a good community to work with, but technology readiness was low with regard to Internet-based technologies. In this case, once the team got comfortable with the technology they became incredibly successful.

NEESgrid is an NSF program of civil engineers interested in effects of earthquakes. They needed an upgrade of facilities in field, so NSF held a competition and would award sites, but NSF mandated that the facilities would have to be available for collaborations. They gave 10 years for consortium development once the facilities were upgraded. The mandates were a shock to the field, because historically, each center had their own way of doing things. The losers would have to use the winners’ facilities. NSF was also pushing them towards computational rather than physical modeling. As a result, collaboration readiness was a huge problem, with clashes between computer scientists and engineers, particularly when it came to language. Things are working better now, but there was a lot of struggle over a decade and lack of collaboration readiness was a huge reason.

At the International AIDS Research Collaboratory, there was less developed technical infrastructure in sites in Africa, and the team members brought a more mixed skills, but there was high motivation driven by science needs. As a result, the group was able to overcome issues with donated technology.

These three case studies demonstrate that collaboration readiness is necessary but not sufficient, that it interacts with a number of other factors, and that details of collaboration readiness matter.

Dr. Olsen concluded by describing the Collaboration Success Wizard, an online assessment tool that is available in multiple versions based on where a team is in its development. It provides a report at the end with red flags and remedies for improving the team. The Wizard was tested in the UCI Medical School’s CTSA, and the results were incorporated into their NIH proposal, which was funded. Judy Olson provided a demonstration of the Collaboration Success Wizard at the conference.

**Collaboration Readiness and Conflict Resolution**

*Verlin Hinsz, PhD, North Dakota State University*

*Professor of Psychology*

Collaboration readiness is a disposition to act in a collaborative way. Science is a personal/interpersonal/team/institutional endeavor, but collaboration is an outcome. We think about the behaviors that are critical for team science – the “readiness” here is a future orientation, we are preparing, it’s an attitude, a predisposition to act. Collaboration in team science is a motivated behavior, a type of interpersonal behavior.

The outcome is the collaboration, and the precursor is collaborative behaviors. These behaviors are shaped by the intention to act collaboratively (have to want to do this) and the current habits and routines, the past history of collaboration, and the perception of control. These attitudes are an affective response, a gut-level response. There are considerations of the perceived consequences to working collaboratively, the social forces (what does the dean, provost, department head think), and the belief of scientists that they are able to act collaboratively.

With regard to conflict in teams, Dr. Hinsz differentiated between task conflict (differences in ideas, opinions, and viewpoints about task content), relationship conflict (tensions, annoyances, disagreements, and personal incompatibilities over matters such as beliefs, habits, and personalities), and process conflict (disagreements about duties and resources, standard operating procedures, and strategies for coordination). Each type of conflict can be affective, behavioral, and cognitive in nature—the ABCs of conflict. Though it might be possible to conceptually differentiate between the types of conflict, the actual conflict is usually a combination.

Antecedents of conflict can have origins in affect, behavior (resource allocation, research funds), and cognitive (dictating the terminology used, processes used). The consequences of conflict in teams can also be affective (commitment declines, soured), behavioral (sabotage to data site), and cognitive (coalesce around enhanced view of risk).

The nature of conflict is multi-faceted, inherent, and inevitable for interpersonal tam interactions, particularly in interdisciplinary teams. Because conflict can’t be avoided, we must be able to anticipate, intervene and manage conflict early. If you ignore it, it will not go away. Importantly, conflict can be destructive or constructive.

Dr. Hinsz described some remedies for conflict in teams. With regard to affective sources of conflict, don’t underestimate the power of success, even the little successes, and the importance of psychological safety. If a leader can make people feel secure in the environment, they will feel better about taking risks. For behavioral sources of conflict, negotiated agreements and development of norms can reduce conflict. Shared representation can address cognitive sources of conflict. Other approaches for dealing with conflict include the establishment of superordinate goals, management of expectations, training, and giving team members a voice.

Dr. Hinsz concluded with a few words about motivation. Collaboration is a class of motivated behaviors, and it is crucial that the motivation for the collaboration is managed. Context and environmental barriers (i.e., institutional policies) can frustrate collaboration and reduce motivation, as does conflict. Team members will need reinforcement of incentives to collaborate.

**Panel Question and Answer Session**

**Q:** Who actually should be doing all these things to keep the team successful? Team leader are growing increasingly resentful about dealing with the collaboration because it is taking them away from the science.

**A:** Far more time is spent on the conflict side of collaboration than is necessary. It is important to spend some time up front to avoid those conflicts.

**A:** One of the things we’ve discovered is that when people integrate this stuff it becomes more unconscious and won’t take as much time.

**A:** Recovering from difficulties is always more time-consuming than addressing them up front.

**A:** Is it a resistance to the idea of teamwork or are they too busy with task work? It could be a matter of convincing them of the benefits and values of teamwork – is a culture shift.

**Q:** They’ve been collaborating for decades and have been overwhelmed by the team administration.

**A:** It’s a discussion about goals, roles, and responsibilities. There are tools to make this easier and they are things that need to be discussed anyway. These things need to be quickly outlined so that the team will have something that they can come back to.

**Q:** Once a collaboration starts, particularly in virtual teams, they can fall apart, primarily because of less frequent sharing and communication. How much of that exacerbates the problems outlined this morning? What mechanisms are teams using to keep work flows going?

**A:** Managing virtual teams is not the same as managing co-located teams. You need more proaction on the part of team leader. The best virtual teams are managed well.

**Q:** In the small group communication literature there are zero history groups and development of identity and organizational development as ropes courses for team development. What can we do ahead of time to engender trust to encourage team success?

**A:** Having awareness about the need for trust is helpful. Do things together outside the lab environment—those things alone aren’t going to build trust, but can add to it.

**Q:** There’s two things happening. There’s team readiness and organizational readiness. How often have our funders measured the readiness of the organizations to do collaborations and avoid the affective sourness that occurs?

**A:** Since the literature is expanding and our conversation is advancing, the grants, the applications, and the teams are being evaluated on technical merit, and there are some evaluations that indicate that a team is failing not on technical side but on the collaboration. There are no formal evaluations for collaboration readiness. Site reviews might be one way to judge this. It’s all ad hoc, but not a part of grant review process.

**A:** In the last decade, the NSF has made it a requirement to explicitly address how you are going to manage your project in your proposal, and they even give you extra pages to do it, so they recognize the importance of this. Proposals are turned down if they are too vague on how they are going to make their team. We hired someone with business experience to help manage the project; it took a shift in attitude, but the team was adrift and the investment paid off. We like to think that the money is going to the research itself, and that we shouldn’t spend money on management, but it is actually critical to have project management to allow us to do the research at all.

**Q:** A whole new generation is coming up that live their lives in virtual space.

**A:** This is technology readiness, and there are generational differences. There are senior, well-recognized scientists who wouldn’t touch a keyboard, even though there are tools that can help their teams work. As young investigators come up through the ranks, I think we will see a shift.

**Q:** The ability of the group to move through conflict is more important. Have you had experience in taking a model and converting it into a training intervention, in order to make inroads in rating the emotional intelligence of the group?

**A:** I have not had experience with it, but it is a model of how I interact with my students and graduate students. Going back to the point about expectations—trust is a set of expectations on how you interact with your team members. Once you lose trust, it takes a long time to get back. We want to manage conflict while still maintaining trust.

**A:** Trust is a huge challenge in virtual teams

**A:** Conflict assessments are a worthwhile effort to understanding own approach to conflict as well as others’ approaches.

**Q:** How do we get people to work together while avoiding conflict?

**A:** There is an optimal level of conflict at which teams are effective. You need conflict for give and take, but it takes skill on the part of the leader to reach and maintain that level.

**A:** There are many studies that unpack what we mean by technology issues, optimal distributions of teams.

**Q:** There is a tendency to ascribe a conflict to a parochial difference – that department is “just that way.” What’s a best way to short-circuit that argument so we can work through the conflict?

**A:** Sometimes those parochial differences are real, but the key is the superordinate goal – we must keep in mind and communicate that combining skills and knowledge is the best way to get us to that goal.

**Keynote: Cyberinfrastructure and Datasets for SciTS Research**

*Katy Börner, PhD, Indiana University*

*Professor, Information Science, Informatics & Computing, Statistics; Director, Cyberinfrastructure for Network Science Center*

Dr. Börner started by acknowledging all the input she has received on how to make the cyberinfrastructure for the science of team science better. She stated that her presentation draws heavily on a paper published based on last year’s SciTS conference, “A multi-level systems perspective for the science of team science” in *Science Translational Medicine*.

She discussed the needs of mixed-methods multi-level SciTS research and practice: the ability to identify and access ***expertise*** at the perfect time (using social networking tools); the ability to find, understand, apply, and advance ***theories and methods*** of team science (repositories of information like on the northwestern SciTS site); the ability to find and use ***data*** (using Web sites analogous to diggingintodata.com, SDB, or LOD); and ***tools*** that help identify, learn, and advance (for example, Plug-and-Play macroscopes).

In fact, Dr. Börner noted that just looking at the evolution of the panel sessions and the endnote library of this conference would be an interesting SciTS study project in and of itself.

**Expertise**

How so we find and access the right expertise at the right moment using various systems? Dr. Börner asked to see a show of hands on how many people are using LinkedIn (about 20), and how many are using Academia (about 5). There are many other systems that are used for policy makers at the institutional level, but they are not ready for public use yet.

VIVO is another tool the can help show who has what expertise and who are potential collaborators. Any tool like this must be dynamic to capture how people move in and out of the team. Importantly, VIVO uses high-quality institutional level data, and is able to capture statistics on things like how many PhDs are trained and how much money is spent per day. There are also features that allow topical analysis (what), temporal analysis (when), network analysis (with whom), and geospatial analysis (where). SciTS researchers also need to answer these questions at every level (micro, meso, macro), and so VIVO can compare individual schools and investigators over time, and can overlay expertise over a basemap or landscape of science.

Dr. Börner described the application of VIVO to a small group of network science researchers at Indiana University, and it was informative to be able to load all the information about these researchers into VIVO and see all the different departments involved, all the publications, all the grant intake, and all the courses they teach. It’s information that is important for researchers to find mentors, for incoming faculty, for speakers who are coming in to the university and want to connect with certain IU faculty members.

**Theories and Methods**

Dr. Börner moved on to theories and methods and how SciTS researchers and practitioners can find the right ones and advance them across disciplines and at multiple levels. The NUCATS SciTS Web site is an incredibly valuable resource, as is the Team Science Toolkit from NCI that was officially revealed at the conference. There are tools, measures, bibliographic entries, funding opportunities, news, events, and job announcements that are made available for exchange using a wiki-based platform. Users can freely upload and download publically available team science resources, which will help reduce the replication of resources and accelerate advances in the SciTS field.

Hub Zero is another group that operates across different disciplines to create dynamic Web sites for scientific research and educational activities. These technologies support community portals and there are good examples of what to do and not to do that we can learn from.

**Data**

Dr. Börner asked how many in the audience have more than a terabyte of data to work with. Ultimately we want to be able to analyze all kinds of data from science, not just publications, patents, and funding data. We also want data about science news, science jobs, and even qualitative data about science. We need large-scale maps as well as highly specific data.

Dr. Börner showed some exemplary efforts to create tools that help find, access, interlink, and merge data. From the arts and humanities, there is the Digging Into Data challenge. It is a core site that links to publically available data and contact information. This kind of data repository would be great to have for SciTS. At Indiana University, we have the Scholarly Database, which allows access to 25M papers, patents, grants. You have to sign in to describe what you are going to do with the data. You can search for authors, titles, and key terms across data silos, download data, or load them into assessment tools to see and analyze networks.

The Semantic Web linked open data interlinks data silos and exposes them as structured data. In many cases, these datasets are high quality and are linked together in to a cloud that is highly valuable. Within the last 3 years, the linked open data cloud has grown exponentially and now include the VIVO data.

Ultimately, it will be great to have national and international research networking to visualize scientific efforts holistically, and having the data open and freely available is essential.

**Tools**

Now that we have these terabytes of data, it is necessary to have tools to deal with the large-scale datasets. One approach is the “plug-and-play macroscopes.” These tools are helpful for SciTS, but they can also be used by anyone who wants to make sense of very large data sets, beyond SciTS.

Dr. Börner asked what it would take to design a “dream tool.” Many of the best micro-, tele-, and macroscopes are designed by scientists keen to observe and comprehend what no one has seen or understood before. We wanted to design our own tools and were not sure that computer scientists needed to be involved. We designed our own, but we wanted to inspire computer scientists to start designing these tools so we published our work in the *JACM*.

Macroscopes provide a “vision of the whole,” helping us “synthesize” the related elements and enabling us to detect patterns, trends, and outliers while granting access to myriad details. Rather than make things larger or smaller, macroscopes let us observe what is at once too great, slow, or complex for the human eye and mind to notice and comprehend. They are not static instruments, but are continuously changing bundles of software plug-ins that allow you to look at data every day. New datasets become available every day, and we needed a site like Flickr and YouTube, where we could see new data sets and use them if they fit our needs. We wanted a way to plug and play those datasets into a dream tool.

Many people are sharing code, but we need a better way to customize tools to get the information that you want out of the data. Science is becoming more data driven and computational but also collaborative and interdisciplinary. There is increased demand for tools that are easy to extend, share, and customize across different disciplines. The star scientists are now research teams, users have become contributors, disciplinary research is becoming cross-disciplinary, we are studying data streams across several specimens, and we are moving from static instruments to tools that can track the evolving cyberinfrastructure.

The workflows for dealing with the data are long, and we need better, faster, and flexible tools. We used an OSGi infrastructure and added CIShell with sockets for various tools. There is no need to hire a computer scientist for the lab, you just get the tool and integrate it into your workflow, take the shell and fill it with your relevant plug in tools. Some examples include the Network Workbench Tool and the Sci2 Tool, and give the user the ability to perform network, spatial, and topical analyses. There are tools being developed that are open access that can be just downloaded and plugged into the shell.

Dr. Börner concluded that we have more efficient ways to access data, tools, theories, methods, and experts, so that we don’t need to have a computer scientist or programmer in the lab. One caveat is that we must have the highest quality data to analyze—and it must be open access data—so you can cherry pick the most relevant data to your research.

**Questions and Answers**

**Q:** Do you offer a way to validate these tools? Who is validating them?

**A:** As soon as you can get to the source code, you can look at code. These macroscopes or shells are filled with active code, so they may be filled with viruses and worms and then served to the world. That is a nightmare of mine and the important thing is to brand that tool so that you can validate it yourself. The developer signs their plug-in with their name and reputation. There are a small number of projects using these approaches, and as long as you download it from us, you should be okay.

Some people use the shell internally with no intention to share it. I hope they do eventually share in return for citation counts. Right now, we have tests of the code, and those people who offer these tools as companies have the money to do these tests. Ti is hard to justify the validation/test step using NIH funding. I don’t’ think we could offer 24-hour service in an academic setting.

**Q:** I am amazed at how long it takes to clean the data, and thinking about this as a national priority—to get clean, tagged data that can be used in a Semantic way. There are some things in industry that we can do with funding in academia, but not all of it.

**A:** The best way to finance this is that some of us take care of one of these many bubbles of data. There is no way one institution can take care of all of that data—we have the Scholarly Database at IU and we are exposing all the patent, NIH, and NSF data. But there might be other people who can expose Medline data. Others have qualitative data and it should be in there and have their name on it so was can link to it. If we all make the data available, we will get there eventually. We need to try to make it available by Linked Open Data. There are people who retire or run out of money and don’t take care of their data, and their graduate students become the stewards, the curators of the dataset. This is a good approach given our funding situation.

**Panel Session: Cross-Disciplinary Training for Team Science**

The panelists discussed core facets of cross-disciplinary intellectual orientation and described alternative strategies for nurturing this orientation in students and scholars at various career stages. They discussed best practice techniques for training college students and described a recently developed methodology for designing and evaluating interdisciplinary educational programs. Throughout the presentations, the panelists addressed emerging issues in the design and evaluation of cross-disciplinary training programs as a basis for enhancing the science and practice of team science.

**Nurturing a TD Intellectual Orientation**

*Daniel Stokols, PhD, University of California-Irvine*

*Chancellor's Professor, Planning, Policy and Design; Psychology and Social Behavior*

Dr. Stokols discussed ways to enhance the capacity of individuals to participate in team science. He asked PIs to rate themselves in terms of their role in the team and their departmental affiliation to get a read on how closely different PIs work. He found homophily between biomedical scientists (share close space, but have knowledge diversity) but the relationships were more diffuse in the social sciences and humanities.

There may need to be some training that goes on in groups that work closely together on a shared project. These include project-specific, short-term strategies and longer-term modalities intended to cultivate an enduring cross-disciplinary intellectual orientation among students and scholars. Training must change the CULTURE, BELIEFS, and ATTITUTES toward cross-disciplinary research.

Transdisciplinary training must train scholars to synthesize concepts and methods from different fields that pertain to particular research topics. The transdisciplinary intellectual orientation is a set of personal attributes that emerges gradually over the course of a scholar’s career and is shaped through exposure to multiple learning environments, mentors, and research settings.

The key facets of a transdisciplinary intellectual orientation are:

* Transdisciplinary ethic- a set of strongly held values that predisposes one toward acquiring a broad understanding of research and societal problems; the motivational core of a transdisciplinary orientation
* Attitudes – favorable toward engaging in integrative scholarship bridging multiple disciplines
* Beliefs – that integrating concepts and methods from diverse fields is essential for achieving important scientific and societal advances
* Conceptual skills and knowledge – that enable scholars to traverse multiple levels of analysis, synthesize disparate disciplinary approaches, and develop novel conceptualizations that transcend pre-existing constructs and theories
* Behavioral repertoire - conducive to learning about and synthesizing concepts and methods from disparate fields, and collaborating effectively as a research team member

The values associated with a transdisciplinary ethic are inclusive rather than exclusionary toward other perspectives, open-minded, tolerant, respectful towards others, place emphasis on pluralism rather than determinism when considering the causal structure of scientific and societal problems, and include a desire to promote social justice and environmental sustainability.

Transdisciplinary attitudes include a favorable stance toward opportunities to collaborate with others in cross-disciplinary research; a view of cross-disciplinary studies and the societal outcomes of such research as highly valuable; a positive stance toward persisting on complex tasks, even when confronted by logistical, interpersonal, or conceptual challenges; and favorable attitudes toward the processes and outcomes of cross-disciplinary inquiry may be rooted in more general and enduring personal dispositions such as psychological hardiness, optimism, perseverance, stamina, adaptability, intellectual curiosity, tolerance for uncertainty, and willingness to take risks.

Transdisciplinary beliefs are that the benefits of collaborating with other scientists outweigh the costs of such work; that one tends to be equally or more productive working as a member of a collaborative research team than they are when working on their own; that the kinds of evidentiary support that are required for validating scientific measurements and findings; that the value of research stems as much from its applicability to community problem-solving as from its potential for producing basic discoveries; and that one’s efforts to integrate concepts and methods from diverse fields, and collaborate with fellow scholars across disciplinary and geographic boundaries, have led to or will result in innovative theoretical insights, significant empirical discoveries, enhanced scholarly productivity, and translations of research findings into societal improvements.

Transdisciplinary conceptual skills and knowledge include the ability to view research and societal problems flexibly from multiple levels of analysis; the capacity to achieve an integrative and contextual understanding of the multiple causes and consequences of complex problems; an integration and implementation sciences, including systems thinking, participatory methods, knowledge management strategies; ecological and contextual analyses; and ways of incorporating diverse analytic perspectives and world views into novel conceptual frameworks (e.g., multi-level analysis, analogical and visual reasoning skills).

Finally, transdisciplinary behaviors include reading articles and books, taking courses, or attending conferences and presentations outside of one’s primary field; engaging in frequent meetings with colleagues from different disciplines to share and integrate ideas; communicating with colleagues respectfully; gaining extensive experience working collaboratively in transdisciplinary research projects and centers; and facilitating transdisciplinary collaboration with and among colleagues—especially acting in ways that enable them to cooperatively develop and openly share their ideas, as well as negotiate and resolve intellectual or interpersonal disagreements.

Ultimately, Dr. Stokols would like to see educational and training strategies that communicate these values, attitudes, beliefs, and behaviors that support collaborative, transdisciplinary team science.

**Association for Integrative Studies**

*William Newell, PhD, Miami University*

*Professor of Interdisciplinary Studies and Executive Director, Association for Integrative Studies*

There are terminologic distinctions regarding what students need to know and appreciate: Interdisciplinary science (IDS) processes (integrative studies), interpersonal challenges (SciTS), engagement of stakeholders (transdisciplinary studies), and complexity (complex systems theory). Dr. Newell is convinced that the advocates in these four fields need to learn as much as possible from each other and put together an integrated training program.

As far as the process, in part 1, we will need to draw insights form disciplines into a particular complex problem, and then in part 2, integrate their insights into a more comprehensive understanding of that problem. The thinking skills needed for part 2 of the process are difficult, and must be holistic, contextual, and systemic; they must involve a spectrum or continuum, interacting levels, and interdependent causes; they must synthesize/integrate, and take in to account ecological and co-evolving issues; and the thinking must embrace overlap, interpenetration, tension, and mutual contradiction. This is not the reductionist type of thinking that we are taught in school.

Case Studies in Interdisciplinary Research was published in March 2011 by Sage, and provides examples of research using the 2-part process in various disciplines, as well as a critique of the process. There are also resources available on the AIS Website, including a research manual for interdisciplinary senior projects and other reference materials.

Dr. Newell concluded by suggesting that interdisciplinary scholars reconcile different perspectives to create common ground, overcoming diametrically opposed assumptions regarding rationality, autonomy, and trust, and transforming yes/no axioms into continuous variables.

**Cross-disciplinary Training for Team Science: The Role of Integration and Implementation Sciences (I2S)**

*Gabriele Bammer, PhD, The Australian National University*

*National Centre for Epidemiology and Population Health*

How do universities better support societies’ need to solve problems? What methods should be used? The aim is to support not only inter- and transdisciplinary research, but also any research on complex real-world problems, using integrative applied research that draws on insights from inter-disciplinary, multi-disciplinary, trans-disciplinary, team science, etc.

Dr. Bammer described a systematic approach with three key domains and a five-question framework. The three domains are: synthesis of disciplinary and stakeholder knowledge; comprehensive understanding and management of unknowns; and provision of integrated research support for policy and practice change. Each of the three domains then has five questions that need to be answered. Dr. Bammer described how each question can be “unpacked” to see what is being dealt with within the question and what kind of information can be gathered.

She is trying to find a framework that can be a repository for methods of training. Several people are developing these domains theoretically or empirically, and Dr. Bammer asked whether we combine them all in this three-domain/five-question framework. What are we trying to do? How are we doing it? What is the context?

As far as teaching style, they use a small group, hands-on approach with limited didactic instruction. There is built-in time for reflection, and group learning and sharing allows us to build a “college of peers.” These are professionals, not students, and we try to make the groups as diverse as possible.

One course that is offered is for research leaders who already do this kind of research (integrative applied research). The course gets them to put their own work into the framework and share with others the skills and methods they have developed. There is also a 6-week course directed at Asia-Pacific research leaders who have no experience in this type of research, though they are focusing on an area that they’d like to expand into policy. They are at a research-policy nexus, and we help them think about how to get their research into government policy. They develop a policy brief and action plan, as well as a case study, and we follow them for a year using an alumni network. These people come from very different countries, and the course forces them to share knowledge and be open other ways of doing things.

Dr. Bammer concluded by discussing next steps. First, she would like to build a repository of intellectual elements—concepts and methods for using the systematic approach; second, there is a political element and the challenge is to agree on the prime way forward and what framework to use. Do we need an underpinning discipline? We definitely need to have a hard conversation to ask ourselves how we can be more influential.

**Teamscience.net**

*Bonnie Spring, PhD, Northwestern University*

*Professor, Preventive Medicine and Psychiatry and Behavioral Sciences*

Dr. Spring restated the goal of the conference: to find out how to bring scientists together across disciplinary boundaries into successful teams. The successes are spectacular but most of these teams fail. It is a risk to take with people’s careers. It would be nice to be able to provide training to reduce that risk.

The teamscience.net training development used ARRA funding as a CTSA supplement plus other funding sources. The ideal platform is durable, accessible, scalable, and easily disseminated to a large audience across disciplines, as well as engaging, effective, and broadly applicable.

Her group decided to use the Web because it provides an easy method for free dissemination, it is efficient, allows self-study, and facilitates active learning that deepens learning and increases retention. The Web-based platform also provides mechanisms for feedback, which also complements classroom learning.

The application was developed by NogginLabs, Inc., by developers who were trained by Roger Shank, an active learning theorist who believed that people learn best by asking experts and making mistakes (in a safe environment). NogginLabs recreates this experience online using an Ask model.

Dr. Spring showed the introduction of the program and described the four “wings” of the virtual space, including a resource center and 3 projects. The user navigates through rooms and creates an optimal environment for a particular team project, answering interactive questions, and applying new knowledge to relevant situations and problems faced by researchers who are working in teams. Soft skills are also being covered; such as conflict resolution and negotiation. Finally, users learn how to evaluate projects, and self-assessments throughout the program test the users’ knowledge.

**Panel Question and Answer Session**

**Q:** How would you imagine the connection between presentations. Is there a consensus?

**A:** We are looking at a continuum of strategies that are designed for teams at different stages. For teams just forming around a grant, you could use teamscience.net. For training the next generation, you would need to develop college curricula. Some strategies would be implemented early and some for advanced scholars, and there is a package or suite of strategies represented in the presentations.

**A:** Each of us is coming at the problem in different ways and we don’t have an agreed upon overall view. We’re not the only ones who are faced with this – everyone is approaching it in a different way, looking at different pieces, and we need to find larger strategies moving forward.

**A:** We want to start the dialogue, to stimulate discussion about the best way to train in interdisciplinarity. There is no vocabulary for many of the challenges – we’re just trying to find words for the discipline – tools, context, and intellectual matter to grapple with the challenges they face in science.

**A:** The more you can articulate the goals of inter- or transdisciplinary training, the better chance you have to get there. We need to identify the skills, values, and behaviors we need to cultivate in people if they want to collaborate in a team project so that they can be successful. We need to know what we’re training toward or for.

**Q:** Where do you start to introduce trans-disciplinary training at a university – if we had to focus on one group? Early career investigators because they are at risk or senior investigators because they are harder to change?

**A:** Graduate school, even the undergraduate level. This is all about forming a gestalt, a way of thinking about the world, and the sooner you validate these kinds of thinking, the more students will see and do later on the silo-busting work.

**A:** All online training is focused on early career because they are open to it. Go later to the more established practice because the early adopters can make it clearer to senior investigators.

**A:** I don’t think that approach has gotten us to where they want to be. We need the senior people on board first so that the undergrad and grads can have mentors and examples.

**A:** There are probably a set of scholars that should not get this kind of training – some predilections are not for teams, and they shouldn’t be made to feel that team science is the only way to do things. It’s a matching thing. There might be an index for people who are more or less likely to succeed in team science.

**Q:** What do you tell a senior research who feels that there is not enough depth – how do you convince them that we need more breadth?

**A:** This is a big problem. It took years to establish depth in each area before we could go back to breadth. Core curricular courses first in broad ideas, and then delve into discipline. Others will have a broader curriculum the whole way through. The students self-sort depending on their interests.

**A:** When I started teaching interdisciplinary science, I would argue that it’s all about breadth, but I think that we have developed increasing depth in the interdisciplinarity and we need to resist the notion that depth is a phenomenon of disciplines and that anything we do is superficial by comparison. These interdisciplinary fields have evolved and have their own depth.

**A:** That is one reason for making interdisciplinary research its own discipline, albeit cross-cutting, like statistics. That has tools that can be applied across disciplines.

**Q:** How effective are these training approaches to getting students to think about the unknown?

**A:** Getting students to think about transdisciplinary, transformative research is difficult because they are often trained using an apprenticeship model. But that should be the goal and people need to be encouraged to think that way. It’s not for everyone, but for those who are inclined, they should be encouraged to think outside the box and come up with risky ideas.

**A:** We’re nowhere near as comfortable thinking about the unknown than the known. We need to think about the unknowns in new ways. Each discipline has its own way of contemplating a particular kind of unknown, but when you look at unknowns across disciplines, you need other taxonomies and language. We are just scratching the surface.

**A:** Anticipating the unanticipatable – the nature of the problems that interdisciplinary and transdisciplinary research focus on is complexity, they have these unanticipated paths and pitfalls. Either they involve a linkage between one aspect and another of a complex system or they come about because of a failure to sufficiently contextualize the problem and in a sense, that what you do when you add another discipline to a team because you are adding a new context. In principle one could educate students in how to go about identifying and specifying linkages and going about systematically and identifying context and seeing if there is a linkage in this particular context. We can deliberately and systematically try to address these unintended consequences. So many policies end up failing because they do not anticipate the unanticipatable.

**Panel Session:** **Multi-team Team Science**

This panel presented an integrated multi-team system (MTS) perspective on science teams, beginning with an illumination of the nature of the unique issues that arise when teams collaborate as part of large systems of teams. They explored the motivational dynamics that arise over time in MTS environments, and considered the shared and vertical leadership of scientific MTSs. The panel concluded with some empirical evidence that bears on the nature of these motivational and leadership issues as they operate in multi-team environments.

**The Social Structure of Team Science: Insights from Multi-team Systems Thinking**

*Leslie DeChurch, PhD, University of Central Florida*

*Assistant Professor, Industrial/Organizational Psychology*

Dr. DeChurch posited that what we have been describing as science teams is not a team at all, but an organization of multi-teams. For example emergency medical services and provincial reconstruction teams are linked with a higher level, distal goal, but there are conflicts among parts of the overall team because they have difference proximal goals. The unit of analysis is the multi-team system, not each individual team. Individual team members are thinking, feeling, and doing as they form teams, and then the teams are thinking, feeling, and doing as part of the multisystem team.

Dr. DeChurch described the core features of multisystem teams: they are larger than teams and usually smaller than organizations; they can be contained within an organization; they have a ***goal hierarchy***—each team has its own proximal goal, and then a larger goal that is achieved by all the teams in the system; there is interdependence in that component teams have input (share resources, funding), process (behaviorally interact), and outcomes (work together to gain a goal) with at least one other team in the system; and the component teams exhibit actions that unfold over time via a recurring phase model, called a ***team performance episode***.

**Leadership in Science Multiteam Systems: A Conceptual Framework for Some Research Propositions**

*Stephen Zaccaro, PhD, George Mason University*

*Professor of Psychology*

Dr. Zaccaro continued the discussion by explaining the specific leadership needs of multisystem teams. These teams are set up to solve big issues that can’t be solved by organizations—for example, the BP oil spill crisis. In that example, there were teams deployed to determine the effects of using oil dispersants (proximal goal), and then policy teams that would make a recommendation (distal goal). It is essential to look at a goal hierarchy within multiteam systems.

How do we make these multiteam systems work? We need to understand that what happens within AND between each component team is important. The dimensions of multiteam systems include compositional attributes (number, size, diversity, geography, motive, etc.); linkage attributes (interdependence in the goal structure, hierarchal arrangement, power distribution, communication structure); and developmental attributes (genesis, tenure, stage, transformation of composition). This is a new taxonomy that is currently in press (Zaccaro, Marks, DeChurch).

Multiteam processes and effectiveness follow a classic ITO model that appeared in literature in 1964, but when it is extended to multiteam systems, it is expected to become much more complex and also specific to particular systems.

Science and policy multiteam systems are likely to include teams from both research and policy organizations, which introduces organizational and functional diversity. International teams will have additional geographic and cultural diversity. Communication patterns may lead to groupings of similar functional teams; different motive structures may lead to ***“co-opetition”*** around idea ownership and intellectual property; and team linkages may shift over time.

Leadership in multiteam systems takes place within each team, between teams, and between the multiteam system and the outside environment. In each context, the requirements of the leader and the action processes they must lead are different.

There are also different forms of leadership in multiteam systems, including vertical (fully centralized, hierarchal); vertical (multi-level); shared, where leadership is rotated around the group; shared in which leadership is distributed across multiple leaders by task; and shared by a team of leaders that works together to accomplish tasks (simultaneous model).

Propositions regarding leadership in multiteam systems are that multiteam systems with higher levels of organizational diversity will display less shared forms of leadership; multiteam systems with higher levels of cultural diversity will display less shared forms of leadership; component teams that are linked by sequential and reciprocal forms of interdependence are more likely to use rotated forms of shared leadership than less interdependent teams, or teams with more intensive forms of interdependence; component teams that are linked by intensive forms of interdependence are more likely to use simultaneous forms of shared leadership than less interdependent teams, or teams with more sequential and reciprocal forms of interdependence; and more mature multiteam systems will display greater levels of shared leadership than less mature systems.

Interest is growing in MTSs since the term was founded in 2001 and represents a rich area for future research.

**Motivation and Performance in Teams Within MTSs**

*Ruth Kanfer, PhD, Georgia Tech University*

*Professor of Psychology*

Team member motivation does matter for the greater team and for the multiteam system’s success. Team members differ with respect to traits that can affect team motivation and behavior. Motivation in team science includes motivations for being in a team, staying in a team, performing taskwork, and knowledge sharing.

In a resource allocation model, individuals have a capacity (attention, time, resources) that they can apply to a problem, and they allocate those resources on that problem based on their aptitude, skill level, etc. Once the allocation is made, there is a self-regulatory process (self-monitoring, self-evaluation, self-reactions) that occurs. There is also a corresponding set of team actions: self-correction, monitoring, debriefing, and team reactions.

There are three determinants of motivational processes: on the individual level, they are Content, Context, and Change; on the team level, they are Culture, Context, and Adaptation. Context refers to the task or team demands; they change dynamically over time and influence how much allocation an individual will give to the team. Content refers to team member characteristics: knowledge, skills, abilities, motives, personality traits, values, attitudes, interests, styles, etc.

Team composition variables include general mental ability, knowledge, and tactical and technical skills, and the selection of team members occurs on the basis of their potential for contributing to team science.

In contemporary team research, there are individuals who are self-managing and empowered. Motivation plus talent will always beat mere talent. The idea is that member motivation will lead to team motivation will lead to the multiteam system motivation. Therefore, the selection of team members should take into account the member’s potential for contributing to team motivation and the team performance outcome. There is a general correspondence between individual and team motivation and performance.

What personality traits are related to team motivation and performance? The big five are: agreeableness, conscientiousness, extraversion, open to experience, and preference for team work. Extraversion refers to the placement of high value on social interaction. More frequent rewarding social interactions, trust, cooperation, and confidence all develop from each other. Conscientiousness revers to the value of goal planning and attention to detail. These individuals contribute to goal planning and can serve as back up during action processes, so the team gets both efficacy and action performance. Openness refers to a high value on novel experiences; these members develop adaptability that comes in handy when trying to compensate for problems when they arise. All of these traits can be mapped to team performance and motivation.

When we move from teams to inter-professional teams, the person/discipline influences collaboration readiness.

What are the motivation for STEM scientists? Curiosity and intellectual engagement, but not necessarily affiliation, power, achievement, or avoidance. A complex of traits, rather than a single motive, must be considered in designing an environment to promote motivation for team science. The goal is to form synergies, cooperation among members who enjoy the act of collaboration in and of itself for discovery. The payoff schedule is different for each of the motives that can occur within and across teams.

It is important to “seed” multiteam systems interactions to reduce risk and provide psychological safety. It is also necessary to reduce incentive conflicts among the participating teams, and allow for knowledge to be brought back to the “home team.”

In summary, in multiteam systems, homology is the motivational structure, there are dynamic cross-level effects, person characteristics rather than discipline characteristics provide the best prediction for interprofessional team training outcomes, and interdisciplinary motives become more important for collaboration and knowledge sharing. Exogenous factors can undermine or facilitate multiteam systems, including inter-team competition, and differences in reward or leadership factors.

**Good Ties and Bad Ties: Impact of Within and Between Team Tie Density on Multiteam Performance**

*Leslie DeChurch, PhD, University of Central Florida*

*Assistant Professor, Industrial/Organizational Psychology*

Team effectiveness and intergroup relations are in tension. Dr. DeChurch’s group proposed that there are emergent patterns of motivation, affect, cognition, and behavior across teams that are stronger predictors of multiteam systems success than they are for team success.

There are planning, coordination, and trust ties that exist between team members within or between teams. How do these ties impact team performance? Which types of ties are most predictive of team performance? They did a laboratory simulation of 114 6-person multiteam systems made up of 684 undergraduate psychology students. The students played a World in Conflict game centered around a humanitarian aid task force. The measured different types and operationalizing levels of the ties between the teams.

Dr. DeChurch’s group found that high density ties between individuals can be bad for system performance but that ties between teams are essential for system performance. She concluded that capturing the dynamics at each level of a multiteam system is necessary because tie density has different effects on performance depending on where the ties are. Apparently, we can build teams TOO WELL. If we go at this with “let’s build teams,” it may actually be harmful. We have to allow a weak internal focus within teams while opening up ties between teams. Essentially, a strong internal focus harms the external focus with strong teams leading to a weak system.

What are the implications for scientific teamwork? The collective states are important predictors of system level outcomes. In particular, we need to focus on cross-team relations, or how members of distinct units perceive one another, and we also need interventions and process evaluation that are targeted at the between-team ties. Examining the whole system as differentiated can lead to erroneous conclusions.

**Panel Question and Answer Session**

**Q:** These are much larger, complex teams than we are usually working with. Everything that we are talking about with research teams, the collaborations between single-institutional labs are also multiteam systems because each lab it its own team. Do you see where PIs forming these collaborations are engaging students and postdocs performing at that early stage?

**A:** These are teams of teams. Three universities, three labs, that’s a multiteam system with all the problems of coordination and leadership. We don’t want to say that every collaboration is a multiteam system. Collaborations with independent labs are not multiteam systems. Multiteam systems are highly integrated, for example, a regional center of excellence with eight labs, with each lab as a team.

**Q:** What is not a multiteam system? Are there any other characteristics outside of integration?

**A:** We got a lot of push back on how you bound it off from other teams – a multiteam system has a shared goal and at least 2 levels of goals.

**Q:** Are certain principles of open systems theory analogous to multiteam systems and how would one try to manage a particular system toward a goal – shared leadership?

**A:** Open systems model: as a multiteam system has an external boundary, there are external functions that the system leader has to deal with, but it is more complicated because more teams are involved.

**Q:** In terms of sciences – is interdisciplinary or transdisciplinary research being done in multiteam systems? There is considerable ambiguity in the sciences that requires constant adjustments to the teams. Are there examples of multiteam systems that are flexible like that?

**A:** That is new ground, and that’s why these cross-team interactions are important to understand. The flexibility may be idiosyncratic based on who is on the team.

**Q:** How is the EMS team an MTS? It seems like a process, not an interaction.

**A:** It’s based on the goal hierarchy – we don’t mean that every team is working with each other, just one or more other teams. If you have a lot of shared goals, the hierarchy will be flatter, it you don’t have a lot of shared goals, it might look more like a linear process. There are some places with interaction, no interaction, and co-action throughout the hierarchy.

**Q:** Can you start applying multiteam systems to community-engaged research and come back in a year?

**A:** What got us interested in this in the first place is how you get greater engagement to get science to policy quicker.

**Q:** Have you looked at issues of group identity and how that affects multiteam systems?

**A:** We showed you analyses we’ve run this week, and the data are coming. We’re so interested in the identity issue because it raises the possibility that you can have identity with the lower level lab AND the higher integrated teams. How do you activate and have strong simultaneous identity at several levels?

**Q:** Autonomous knowledge workers are affiliated but we don’t see the discipline as a team that they belong to, it is not a group affiliation identity. Here’s the sub team, here is the multiteam.

**A:** The key is that they are organized in teams – lab to lab, center to center, but not interfacing at disciplines per se.

**A:** As long as they have a shared goal, we have a multiteam system. The goal structure is what’s truly important to defining a multiteam system.

**A:** If the linking motive is intellectual curiosity, this is great.

**Q:** The BP oil crisis and EMT response examples are different in that one is long term and routine, and the BP is a one-off ad hoc thing. That makes a difference in goals.

**A:** Developmental characteristics, how they emerge, how often, etc. They are truly different. And the multiteam system morphs as crises changes.

**A:** The motivation structures will be different as well.

**Panel Session: Distributed Collaboration and Virtual Science Teams**

The panel reviewed several major research threads bearing on the effectiveness of collaborations involving geographically distributed participants. Starting with a review of key aspects of organizational coordination, the panel examined two case studies from the Open Science Grid, then focused on the lifecycles of virtual teams, drawing on studies of teams using the National High Magnetic Field Laboratory. The panel then analyzed existing cyberinfrastructure to support virtual teams, with an eye toward identifying gaps that need to be filled.

**Do We Need Teams?**

*Thomas Finholt, PhD, University of Michigan*

*Senior Associate Dean and Professor of Information*

All evidence is pointing to the fact that geographically dispersed, virtual teams are increasing, but also that they are less likely to succeed. There is more than reasonable doubt about the value of teams of scientists. The incentives are incompatible: the fiercely competitive nature of scientific nature leads Dr. Finholt to be skeptical about the need for science teams or a science of team science.

Even if we allow that there is benefit, there is the obstacle among scientists to be resistant to organizing in groups. They are reluctant to join committees, we have to convince them, train them, and funding agencies must create program incentives. Team science asks that we transform entrenched work systems. If you think changing the curriculum is tough, take a crack at trying to change the tenure system and incentive system.

We must focus attention and mount exploration in other directions. If something is this hard to do, we need to explore some alternatives. Three principles suggest potential avenues for exploration:

Delegation: technology is reorganizing and reconceptualizing human work. The grid, or cloud, is taking over many of the interactions of humans, negotiating interactions and trust, and acting almost as a digital custodian.

Crowdsourcing: turning over a problem to a diverse group in small, digestible chunks by incentivizing the network, leveraging the network, and leveraging the crowd. There is no group, no leader, and people may not even know they are participating. We will need to know a lot about incentive design to get people to participate, however.

Platform ecosystems: these are extra-organizational, massive enterprises that span universities, organizations, corporations, etc. An example is the iPhone app store. Is this the kind of thing that can unleash creative energy instead of pounding our head against the wall to try and get scientists to do something that they aren’t inclined to do?

Replicating success is a worthwhile goal if we can unleash the creative capacity in the service of HIV/AIDS, cancer, and education. Groups and teams are not the be all and end all, and there are reasons why we are attracted to groups as social scientists, The Einstellung effect states that we tend to view future possibilities and opportunities in light of the things that we know a lot about. This leads to competency tracks, and we no longer explore the opportunity base of alternatives (for example, Kodak missed the digital opportunity, IBM missed personal computers).

Dr. Finholt declared a call to arms that we should be more doing than we have been so far. There are a lot of transformative social activities going on through Web 2.0 and social media, and we need to understand what is possible. From the point of view of accomplishing scientific work, we need to include some of these new approaches, beyond just groups and teams.

**Life-cycle Formation and Long-Term Scientific Collaboration**

*Chris Hinnant, PhD, Florida State University*

*Assistant Professor, College of Information*

Dr. Hinnant framed his overarching research question: What social and organizational factors best support the transition of short-term, experiment-focused multidisciplinary virtual collaborations to long-term, productive, and innovative programs of scientific research? His research goal is to develop and validate a lifecycle model to support distributed scientific teams through the transition from discrete experiment-focused projects to long-term distributed collaborations, thereby advancing discovery and innovation and increasing productivity. What is the lifecycle of a research goal? How do they form initially, what do they look like, and then how do they change over time? How are goals formed, structured, and communicated to the team, and then how do they end or transform at the end of a project?

The Theory of Information Worlds (Burnett and Jaeger, 2008) describes how information exchange and social interaction are functions of the specific contexts, or worlds, in which they occur, including social norms and types, information value and behavior, and how information worlds interact with one another. Boundaries may be permeable, semi-permeable, or closed; they may exhibit conflicts or cooperation; and interaction between information worlds varies with the extent to which values and norms support or conflict with each other.

Virtual teams and their lifecycles – members are collaborating but not usually physically collocated, so they must use some level of technology-mediated communication. There are also several socio-technical dimensions: time and place, technology, interpersonal communications, structure, and knowledge and how is it shared and viewed. Is there a mutual understanding if people are coming from different backgrounds?

Dr. Hinnant listed the specific research questions being considered:

* 1. Is there evidence that the lifecycle of a virtual team influences the willingness of individual team members to work together again? How does this compare with their willingness to work together again with co-located team members?
	2. Is there evidence that the lifecycle of a virtual team influences the willingness of individual team members to work in virtual teams again? How does this compare with their willingness to work in co-located teams again?
	3. Do virtual teams generate output as measured by patents, journal articles, and presentations comparable to the output of co-located teams working on similar projects? Is there a difference in the amount of time required to generate such outputs?
	4. Is there evidence to suggest that the degree of multi-or interdisciplinarity within a team influences its lifecycle or its outcomes?

Dr. Hinnant’s group studied the National High Magnetic Field Laboratory (NHMFL), where people bring in samples to work in the lab, and come from different backgrounds, from around the world. They used a multi-method approach to study this team, including documentary artifacts, team administrative data, and analysis of the actual team members. They assessed the characteristics of the teams, their use of the magnet and time allocated, and the frequency of use by teams or team members. They also looked at publication data, performed direct observations of various teams and activities to get very detailed data, and also did semi-structured intensive interviews of 30 teams.

Thus far, they have been able to analyze 3 years of archival documentation on 89 3-person teams to look at diversity and productivity. They found that teams with mixed institutional associations were more central to the overall network, and probably acted as bridge notes. High team cohesion was linked to productivity, and high disciplinary diversity and low seniority were related to high productivity.

They are performing the observations now and have done 24 thus far. The teams appear to be hybrid in nature, with a staff scientist helping the outside team, and when they conduct experiments, the whole team rarely shows up. Some scientists do everything themselves rather than hand it over to a team or small subset of the team. There are status issues among the staff scientists.

The technology varies – some bring in their own vintage computers to use the world’s most powerful magnets so that they can run older applications, and communication technology varies greatly. It is interesting that simple technologies (e.g., duct tape and rubber bands) are often crucial to actually doing the experiments.

Interviews are also in progress, with 6 are completed so far. They are interviewing members of teams that were identified through document analysis and observations, looking at social norms, social types, information value, information behavior, project types, and lifecycle phases. All of these vary with the types of work being done, how long the actual experiments take, and how long they stay at the facility. Dr. Hinnant wants to know whether this impacts how the teams interact?

Eventually, Dr. Hinnant’s group will bring the three methods together and the analysis will be used to develop a better understanding of the lifecycles of virtual teams, and to provide support for future publications.

**Cyberinfrastructure to Support Virtual Collaboration by Scientists: How Do We Find the Gaps? (The Struggle to Make Sense of CI)**

*Michael Beyerlein, PhD, Purdue University*

*Department Head and Professor for Organizational Leadership & Supervision*

Dr. Beyerlein is interested in how cyberinfrastrucure (CI) can be designed to optimize knowledge development, storage, utilization, sharing, and learning. What is an enabling CI system? The solution lies at the intersection of disciplines that design and create the CI, policy makers, researchers using the CI, and researchers studying those researchers.

He listed seven assumptions:

* Knowledge belongs to the individual OR it belongs to the network with individuals as nodes
* Knowledge is shared through conversation – in a variety of media
* Knowledge flows through a complex network with social, political, economic, disciplinary, cultural, and personality facets influencing the processes that produce valued outcomes
* Sharing knowledge leverages it, so it grows
* Bridging between experimental, theoretical and practical knowledge for bi-directional flow is essential for impact (e.g., translational medicine)
* Most knowledge work now depends on CI
* Cyber-enabled interaction creates new opportunities

There is a new approach—socio-technical—with overlapping social norms, values, roles, technical tools, and facilities. Social scientists can join with computer scientists, to view research questions through the socio-technical lens, but it’s not easy. Context determines behavior and technology is a huge part of that context. In the socio-technical system of science, social and organizational issues, intellectual issues, intentional and strategic issues, and technology systems are combined.

Cyberinfrastructure is a combination of hardware, software, bandwidth, and people. We are talking about eight different communities in a network with nodes that may not talk to each other. CI needs to bridge across all eight nodes and overlap so that they become truly interdisciplinary, but we’re not there yet. There are new, evolving CI strategies being developed. One question is whether CI will feed back to act on science, will the CI lead us to think differently about a scientific question?

There are 46 theories of learning, 25 views of epistemology, five psychological theories of cognition, six models of the design process, and everything is impacted by sociology, information technology, design, and philosophy. What intellectual framework should be chosen when developing an enabling CI system?

Collaboration is research with a purpose – there are actually levels of collaboration with various levels of interaction. We need to be more precise with the language. There are four pillars of science that have developed across time—experimentation, theory, computer simulation, and data—and the capacity to analyze giant datasets is what we are facing today. How does technology contribute to solving these needs? It can provide shared instruments and databases, facilitate e-communication, allow for shared computational resources, and permit profile matching to link people together.

Hub sites represent a Web-based collaboration environment with interactive simulation tools that are hosted on the hub cluster and delivered to the user’s browser. There is a mechanism for uploading and sharing resources, feedback, and user support. There are also user statistics that can be accessed. NanoHub is a CTSI hub site, built with many familiar open source programs. But CI is not adequate for team science across disciplines because it cannot capture informal meetings of team members, interpersonal communication is necessary to develop trust, among other issues. This has caused problems for designers of interdisciplinary hubs.

**Working Together Apart**

*Judy Olson, PhD, University of California, Irvine*

*Professor of Information & Computer Sciences*

Dr. Olson described the Collaboration Success Wizard, an online assessment tool that gauges collaboration readiness. The Wizard can determine in what areas a team is strong or vulnerable, and what can be done to have a successful long-distance collaboration. The Wizard is based on 20 years of participating in collaboratories (distributed science endeavors, laboratories without walls) and doing a meta-analysis of success in collaboratories.

At a glance, there are 350 examples of collaboratories, structures as bottom-up or top-down organizations, and there are similarities and differences in both technologic and social dimensions.

According to the theory of remote science collaboration, factors that affect success include:

* Nature of the work – the more partitionable, the better
* Common ground – including a common vocabulary, management, or working style
* Collaboration readiness – there must be a motivation for working together, not a mandate
* Management, planning, and decision-making – a need for overlapping work days, a critical mass at each location with a point person, a management plan in place
* Technical readiness – a team will need technology with the right functionality that is easy to use and reliable, that uses a common platform, and provide adequate networking, tech support, and standards for de facto sharing

The Collaboration Success Wizard is a theory based on a set of questions, and it provides a printed report with constructive outcomes. There are currently three versions, and some pilot studies have been done with CTSA and FaceBase.

To access the wizard, a team must apply with description of the project, and a list of emails. The team members are then asked to complete a survey and each person gets and individual report and an overall report. It is a win-win proposition because the SciTS researchers get the data to analyze and the team science researchers get concrete advice that lowers the risk of doing team science.

**Panel Question and Answer Session**

**Q:** Regarding difficulties of organizing scientists into groups—how much of that is attributable to the organization and how much to the nature of scientific work?

**A:** Fields differ in terms of their collectivist orientation. High energy physics has a high level, and it might not be the scientists but a concentration of resources. In industry, people observe a higher level of collaboration between people who are operating under a superordinate authority, a mission that pulls everyone together. Within the corporate boundary there is more cooperation. There are certain personality traits that predispose to working in a particular field or institution – more or less competitive.

**Q:** There are tools that are coming into existence that let you access any data or resource you want without actually being in a physical team. We need to look at these technologies and how they affect the act of science – maybe for next year. The teams will look very different from the teams as they are now.

**A:** You can be connected, but there has to be a motivation to give.

**A:** That speaks strongly to the incentive design. As we move more toward crowdbased activities, we will need an incentive system. Data.gov is actually endangered with the budget cuts. Revolution within government with regard of release of data is unleashing a tsunami of applications generated out of the market. Write in and make sure lawmakers know that this resource is important and very low cost.

**A:** Marketplace idea – craigslist idea – in scholarly activity citation counts are used as currency, training of post docs, this give and take will determine how much information you get from someone else.

**Q:** How do we adapt to other cultural contexts where collaboration is not held as important? Cross cultural collaborations where work days do not overlap

**Q:** With regard to the complexities of putting together a cyberinfrastructure – e-science in England and surfnet in Netherlands connect research institutions and industry. Are we making the problem more complex than it needs to be? All they did was go around and ask about connections.

**A:** I don’t know if we’re making it more complex; we’re just assessing pieces of the problem and looking at them. The tech is changing so rapidly, there’s a tailoring process once a program comes out. In Jan, the fourth leg of science – pedabytes of data now – the issue was that you can’t mine data if you can’t get into it, so the way data is stored is critical. England is building money into the grants for proper archiving.

**Q:** The delegation and crowdsourcing ideas are promising – the examples have some special properties and my impression is that it will be a limited range of cases where they can be used.

**A:** The tendency of crowdsourcing is to solve very small and simple problems. The NSF program in computer science is looking at crowdsourcing to solve complex, problems (Mechanical Turk) such as compilation of technical manuals. I am optimistic that we are in the early days of crowdsourcing – NSF is doing a good job of incentivizing interesting work in this area.

**Q:** For those who are observing the teams – do the teams get the feedback and if so, does that change their behavior at all? Are you getting feedback on how people are using the advice you give them?

**A:** It’s very odd when hard scientists see that social scientists actually exist. We are very foreign to them. But they eventually get used to us. We definitely give feedback to the teams eventually.

**A:** In the wizard, the individual gets feedback right away and then an aggregate report goes to the organization – we have heard that the reports have led to meetings over areas of vulnerability. One thing we’d like to do as part of our research is to compile a list of best practices.

**Panel Session: Funding Opportunities to Support Collaborative Team Science**

The panel began with a presentation of key differences between developing and funding team science vs. individual research and discussed collaborative research funding opportunities available different agencies. The panelists also discussed their agencies’ approaches to assessing and evaluating the effectiveness and outcomes of team science support.

**Collaborative Funding Opportunities for Team Science**

*Holly Falk-Krzesinski, PhD, Northwestern University*

*Research Assistant Professor and Director, Research Team Support & Development, Clinical and Translational Sciences (NUCATS) Institute*

Dr. Falk-Krzesinski listed out the various organizations that support collaborative, interdisciplinary, and team science and directed the audience to the National Organization of Research Development Professionals (NORDP) as a resource for finding out more about these funding mechanisms.

There are many team science structures, from small teams, research centers, and institutes, to consortia and networks, and each structure needs a funding mechanism that can support the network of disparate pieces. Not all the pieces are research; there needs to be support for administration, core facilities, education and training, translation, community and public outreach, and evaluation.

Multiple PI projects are intended to supplement the traditional single-PI model by allowing applicants and their institution to identify more than one PI on a single grant application. This mechanism encourages collaboration among equals when that is the most appropriate way to address a scientific problem, and has been a great opportunity for investigators who are seeking support for projects that require a team science approach.

For multiple PI applications, it is important for there to be a leadership plan in place, with roles and areas of responsibility of the PIs clearly defined, and that establishes the fiscal and management coordination of the project, the decision-making processes for scientific direction and allocation of resources, the mechanisms for data sharing and communication between investigators, the policies regarding publication and intellectual property, and the procedures for resolving conflicts.

There are team science capacity-building mechanisms that provide seed funding for team research building. These grants are not for doing research, but to build teams. The NIH has an R13 mechanism, called Scientific Meetings for Creating Interdisciplinary Research in Teams, which supports teams of investigators from multiple disciplines to hold meetings for the purpose of developing interdisciplinary research projects. They provide support for up to two years. Another mechanism is the NSF Research Coordination Networks, which support groups of investigators to communicate and coordinate their research across disciplinary, organizational, and geographic boundaries. These grants provide funding for up to 5 years.

**NSF Perspective and Lessons Learned**

*Dragana Brzakovic, PhD*

*National Science Foundation, Office of Integrative Activities*

Dr. Brzakovic described that when the NSF set up the Science and Technology Centers (STCs) in 1985, they were struggling with several questions: What is a center versus a large project? How much should NSF prescribe regarding center operation? What is the best way to oversee center activities? What is the appropriate duration for center support? What is the appropriate funding level?

The STCs are a very risky business. They carry risk in research outcomes, in educational goals, and in management risk, which is probably the highest risk of all. Strong leadership is also needed to get all the different parts to work together towards the same goal, keeping people going in the right direction is the most difficult part.

STCs are unique. They cover all areas of research supported by NSF; the award duration is up to 10 years; the level of funding is $1.5-5 million; the required components are research (long-range, large-scale), education, and knowledge transfer; awards are managed by a cooperative agreement, not a grant, which means that there are site visits and reminders that the center has a mission that might be separate from the lab’s; they are co-managed by the STC program and the appropriate disciplines; and there are required management/leadership positions.

The typical STC profile is multi-institutional, with 5 to 10 partners, 15-70 senior researchers, 20-140 grad students, and overall budget $5-$12M and 5 full- or part-time support staff.

Dr. Brzakovic relayed the management and leadership lessons learned regarding STCs: they are small businesses that require sound advice from external advisory boards; they must have well developed capacities for communication and management; they must have a clear strategic plan; and they must be able to deal with accountability issues.

**NCI Center for Strategic Scientifics Initiatives (CSSI): Concept Shop**

*Jerry Lee, PhD, Deputy Director; Larry Nagahara, PhD, Director; and Nicole Moore, ScD, Project Manager, Physical Sciences-Oncology Program, Center for Strategic Scientific Initiatives, National Cancer Institute, National Institutes of Health*

The mission of the CSSI is to create and uniquely implement exploratory programs focused on the development and integration of advanced technologies, transdisciplinary approaches, infrastructures, and standards, to accelerate the creation and broad deployment of data, knowledge, and tools to empower the entire caper research continuum in better understanding and leveraging knowledge of the cancer biology space for patient benefit.

Max Delbruck helped many physicists make the transition to biology, and that is what CSSI is doing - culturing physical scientists and cancer biologists to work on cancer research together – the PS-OC initiative.

The specific purpose of the PS-OC initiative is to generate new knowledge and catalyze new fields of study in cancer research by utilizing physical sciences/engineering principles to enable a better understanding of cancer and its behavior at all scales.

The Initiative is not looking for new tools to do “better” science, but new perspectives and approaches to do paradigm-shifting science that will lead to exponential progress against cancer. The goal is to build transdisciplinary teams and infrastructure to better understand and control cancer through the convergence of physical sciences and cancer biology. We are trying to generate new knowledge and catalyze new fields of study, using current tools and transdisciplinary teams to do paradigm-shifting research.

The PS-OC physical scientist leads the team with a co-investigator in cancer biology or clinical oncology. They are hooked at the hip at the head of each center, and there are currently 10 centers. Each center has 3 to 5 projects plus cores, and must have mechanisms to exchange information between centers as well. Each center is considered a school of thought that brings people in from across centers and from the outside as well.

Funding mechanisms include trans-network projects with pilot funds, center pilot and outreach pilot funds added to a foundational data collection center (CI to support data sharing), cell/tissue collection and distribution center, and PS-OC network activities. All of these mechanisms foster new collaborations, ideas, and perspectives.

PS-OC has network activities that helps foster communication between scientists from different fields. They use a cell line exercise where participants measure everything about the cells and add their findings into a Wiki site. Small teams from different centers and levels then look at the data and bridge between teams. There is also the PS-OC Data Jamboree where investigators and teams meet in person to look at the data. New collaborations are fostered in this way.

Data collection from the network shows that the program is successful. Data collection methods include interviews with investigators, progress reports, outside progress reports (semi-annual), publications, trainees, student exchanges, and new collaborations. Ms. Moore shared some initial findings from first 3 reports, including evidence of field convergence where PIs are publishing in the other field’s journals.

PS-OC outreach pilot funds are available for outside groups to contribute to the center – contact the PI of the center to see if they are interested in working with SciTS researchers.

**Scialog – Accelerating Scientific Breakthroughs with Small Team Science**

*Richard Wiener, Program Officer*

*Research Corporation for Science Advancement (foundation)*

The Research Corporation for Science Advancement was founded in 1912, with the mission of providing catalytic and opportunistic funding for innovative scientific research and the development of academic scientists that will have a lasting impact on science and society. This is a high risk-high reward initiative to advance innovation by small teams. “Gentlemen, we have run out of money. It is time to start thinking.” Ernest Rutherford, Nobel Laureate

Scialog is a combination of science and dialog, and is an initiative in funding, dialog, and collaboration from the RCSA. The objectives of Scialog are to focus funding on early-career scientists, enable higher-risk research that might fall outside the boundaries of traditional funding streams, establish and convene interdisciplinary communities of research, and leverage funding to further support successful lines of research.

Scialog targets faculty in the first five years post-tenure. RCSA has a track record of identifying and funding talented early-career faculty, to have the most benefit. A mid-career award can have a greater impact on success, compared with the impact of the same amount of money given to a late-career researcher.

In 2010, Scialog had a solar energy research focus, vetted 101 pre-proposals, received 78 full proposals, and 13 of 25 awards were funded because they were the most likely to succeed. Scialog has held one conference thus far to identify obstacles, build the cross-disciplinary community, and form teams to write proposals for supplemental funding (to incentivize formation of teams). The conference was a place of facilitated dialog, a concept inspired by the theoretical physicist David Bohm that asks listeners to suspend judgment, to listen without the need for debate, to create the feel of a coffee shop or pub, and share off the wall ideas in “what if” conversations. Nine new teams were formed to write proposals at the conference leading to three collaborative innovation awards. We are now trying to find out if the teams stayed together after the conference.

We also built assessment into the conference. Surveys assessed growth in the network in terms of awareness, discussion, and collaboration connections. Innovative ideas came out of formal presentations and informal discussions. The conference steps moved from unfamiliar to aware after presentations, from aware to discussions after facilitated dialogue, and from discussions to collaborations after proposal writing. We also mapped the network connections, and found that most of the new collaborations formed between researchers who had not met each other before the meeting.

**Panel Question and Answer Session**

**Q:** We need an alternative to Gordon Conferences – what was different?

**A:** It was not hierarchical and competitive. We tried to make a more collaborative atmosphere with exercises that brought people out of their comfort zone and made them think about how to work as colleagues.

**Q:** Do you have other science topics on your horizon?

**A:** Yes, but it depends on who we will partner with. We are negotiating and seeing what initiatives come out of that.

**Q:** To what extent are you looking at something that is interdisciplinary but maybe losing some people who could be making important contributions to the topic? What are some strategies to keep everyone involved?

**A:** We are trying to put out the list of interdisciplinary funding opportunities, but we must have institutional resources that can help form a collaboration. It’s important for universities to fund that service; if you require that the burden is on the investigators to figure out, there is a better chance they will fall through the cracks.

**A:** Interdisciplinary research supports has difficulties matching the ideas and researchers with appropriate funding opportunities.

**A:** We did a bottom up approach, but you can do either – may miss people either way.

**A:** If we see that one of the centers is not communicating directly, we will engage them. We are not confident that our communication is filtering down to the grad student level. We are trying to engage them directly about opportunities in the network.

**A:** Graduate students STC program – each center has its own cultural rules, and we have found that while the STC directors are not happy to meet because they don’t have much in common, the students are willing to exchange practices on how centers are dealing with training. They have a student portal and videoconferencing – it is changing cultures in each center.

**Q:** Disciplinary and methodological plurality – while we’re studying networks, look at connections, but also bring in cognitive and psychology researchers, communication research so you can see how ideas emerge and conflict gets resolved to arrive at the outcomes you are striving for.

**A:** Interested in getting people to work with us for those kinds of research.

**Workshop: Knowledge Management for Collaborative Research: Research Networking Tools**

This workshop examined research networking tools from the main content providers’ perspective—the researcher. Representatives from three institutions provided an overview of different tools and how they are being used to facilitate new collaborations and team science. The workshop also included a discussion of a national research networking initiative focused on developing interoperability between individual tools and creating a federated national network.

**Introduction**

*Holly Falk-Krzesinski, PhD, Northwestern University*

*Research Assistant Professor and Director, Research Team Support & Development, Clinical and Translational Sciences (NUCATS) Institute*

How do we find new collaborators? Right now, we use a fairly low-tech method, where connectivity is relationship-based and serendipitous. People tend to return to previous collaborators, even though the collaboration may become less effective as it goes on. Institutional memory is also hard to maintain and it is especially difficult to go beyond the university. The tools presented today will enable those of us in research development and help actual researchers. These are research networking tools, expertise/profile systems that are cyber-enabled to connect various levels of resources and facilitate collaboration. They include recommender systems, can evaluate research and scholarly activity and allow us to see changes over time.

When evaluating research network tools, NU did a comparative analysis of more than 30 products using 16 criteria. We posted with conference materials, got the faculty-centric perspective, and checked interoperability with other institutional systems. We didn’t want just one more tool that couldn’t be integrated with existing tools. We wanted to minimize faculty data entry but allow control over information. We wanted a tool that was easy to use, gave us the opportunity to repurpose the data for analysis, allowed for connectivity with other institutions, and gave us control of data over time (absolute requirement). We wanted a tool with low time to implementation, cost, FTEs, and effort required by faculty or their proxies.

During the workshop, Dr. Falk-Krzesinski was informed that Northwestern purchased SciVal with Scopus and VIVO. She stated that these were the two best tools for Northwestern, but other tools may be a better fit for other institutions.

**What Faculty Members Want From a Research Information System**

*David Marshak, PhD, University of Texas Health Sciences Center at Houston*

*Neurobiology and Anatomy*

Faculty are important in the design and implementation of research networking systems because they are the end-users. Dr. Marshak went to the literature to find out what other people had done. He found that faculty were not simply the end users of these systems, but created the content, enhanced the quality of the content, and determined the impact of their work based on citations.

What faculty want is to do their research and nothing else, but it is essential for the faculty to use the system and update the information. So there needs to be an incentive to use the system, it has to help faculty and be a part of what they normally do. What faculty does is bring in money with grants and we want to spend as much time as possible on the research needed for the grant.

The chief executive of Mendeley saw a way to network in order to boost productivity. Senior scientists are interested in saving time and doing more and better research. Younger investigators are interested in networking.

Dr. Marshak conducted four 1-hour focus groups of junior faculty to get their feedback on four systems:

• Community of Science

• Research Profiles (Gulf Coast Consortia)

• VIVO (Cornell)

• Digital Vita (U of Pittsburgh)

One popular feature of Community of Science was the funding updates that arrived by email every week, Digital Vita saved time on biosketches, which was a carrot rather than a stick to make it easier on researchers. Some benefits identified by focus groups included the ability to find collaborators, recruit students and fellows, locate resources, identify funding sources, prepare grant applications, and produce documents – everything that was not research but was part of the workflow in their labs.

Other possible applications included filling out CVs, annual reviews, grant documents, IRB forms, equipment grants, and philanthropy (VIVO has this capability).

The disadvantages were that the database was not complete or was redundant, the systems were hard to use, outputs were not in a useful form, information from other institutions was not accessible, and there were unclear privacy and confidentiality policies. It is important that tool developers take into account faculty concerns and workflow when they develop these tools.

**Questions and Answers**

**Q:** Who drove this research?

**A:** Provost Peter Davies wanted to know what was happening with research on campus.

**Q:** Faculty see saving of time as a high priority, but my university doesn’t recognize that. Is this part of something larger?

**A:** Not many are altruistic.

**Q:** People often use or buy software because there is a cost saving that justifies the investment. Is there any other cost saving that can be used to justify its use?

**A:** Time, if you pick the right product.

**VIVO – Enabling National Networking of Scientists**

*Kristi Holmes, PhD, Washington University Becker Medical Library*

*National Outreach Coordinator for VIVO*

Dr. Holmes shared the results of what she called an enjoyable project taking place at an exciting time, asking how we can connect better and more efficiently. The project is huge and being held at 7 institutions, led by the University of Florida, with Cornell involved in development, and Katy Börner at Indiana University doing visualizations. It is a large, geographically dispersed team and Dr. Holmes wished she had heard many of the things from this conference 18 months ago.

Science is becoming much more interdisciplinary and it is hard to find the right collaborators. We are also trying to pull in new collaborators across disciplines, and with a strong history of mentoring and career development, finding appropriate mentors can be a challenge. Support personnel are doing more with less, so it’s nice to have a tool that can help us distribute resources in a meaningful and efficient way.

VIVO is a Semantic Web application that displays RDF profiles about publications, teaching, service, and professional affiliations. It has a powerful search functionality that can locate people and information within or across institutions. VIVO harvests data from verified sources: internal data sources like the HR director, ORSP, institutional repositories, registrar, faculty activity systems, events, and seminars – all of it is pulled in a programmatic fashion, not manual data entry. VIVO can also pull in external data programmatically: publications for PubMed or World of Science, and grant databases from NSF, NIH, and national organizations. Faculty and unit administrators can then add additional information to their profiles.

VIVO stores data in triples of subject, verb, object so that information can be pulled out quickly with a standard ontology. The content is included as part of the Linked Open Data cloud, which can be human readable or delivered to other systems as RDF. This allows the open research data in VIVO to be harvested, aggregated, and integrated into the Linked Open Data cloud.

Each researcher’s page has basic information as well as graph of publications over time, networks of PI and co-PIs, grants, and a snapshot of interests and activities. VIVO can find potential colleagues, showcase credentials, connect with focus areas and geographic expertise, and simplify reporting tasks and link data to eternal applications. For example, to generate biosketches and CVs, you can publish the URL or link in the profile of the applications and display a visualization of their complex networks and where the people are in them.

VIVO can compare different departments and institutions in terms of papers, grants, and patents, etc. The areas of expertise for the university can also be merged against a base map. Geolocalization data can also be merged to show where the research is taking place on a map and then how it changes over time.

The implementation of VIVO is large project that requires both institutional and individual advocacy on campus. We started in the school of medicine campus rather than all of Wash U. Two key questions that must be answered are what data sources you will use and who will be the data stewards. The things that take the most amount of time are not technical, they are dealing with people and what they are doing. Pre-implementation issues include deciding who is going to be on the implementation team. After implementation, the team that maintains VIVO may be different from the implementation team. Once everything is in place, then it is crucial that you get the word out to get people to participate.

Why did we use a library-based support model? Libraries are trusted, neutral entities that have a tradition of service and support and strive to serve all missions across the institution. They are also technology veterans and have IT and data expertise. Library staff have skills in information organization, distribution, usability, and subject expertise, have close relationships with their clients, understand user needs and the importance of collaboration, and know how to bring people together.

Where are we going? The VIVO ecosystem allows us to see things that are important; the data can be used and there are several VIVO projects for which we are seeking funding. We are rolling out nationwide semantic search across all 7 VIVO institutions. We have had almost 7000 downloads of VIVO code in 1 year, and the 2nd annual VIVO conference is going to be held August 24-26 in Washington, DC.

**Question and Answer**

**Q:** Users can update their own profiles? Or do you need to go through an administrator?

**A:** You can do whatever makes sense in your institution’s ecosystem. You can give as little or as much access as you want. At Wash U, we’re in the middle of allowing access by researchers so they can change their profile, load photos, to make it more meaningful. The VIVO 1.2 release has a Sparkl query database – you’ll be able to generate queries and pull data quickly.

**A:** At U of F, we’re doing self-editing or letting proxies do it for you.

**Q:** Privacy? How is this managed from the faculty’s point of view?

**A:** Everything that is there is open and available from other sources – nothing that is on there is not already somewhere else. VIVO is really a central repository of information.

**Elsevier SciVal Experts at the University of Michigan**

*Jeff Horon, University of Michigan Medical School*

*Office of Research*

Mr. Horon spoke about the SciVal product and its implementation at the University of Michigan. He also shared use cases and described what’s next for his institution.

Collexis research profiles and Elsevier SciVal are exactly the same thing. A customizable director of research expertise automatically populates with publication data. SciVal has several sites with clean data that are linked together. To find an expert, you can search by concept, identify experts, refine search and review publication list. The application takes text, converts it, and gives each researcher a “fingerprint.”

We are data extremists at U of M, so we did a CV-by-CV, publication-by-publication validation of the data, and found that it had nearly 100% coverage and accuracy. SciVal is also easy to use, which improves user experience and adoption, and administrative us. SciVal is also being used in tenure and promotional decisions and annual reviews.

The fingerprints are aggregated from various levels to see who is working with who and to see in what areas the institution is excelling. SciVal can also look at grants from NIH Reporter and perform network analysis with on-demand visualization showing internal and external collaborators.

The impetus for implementation of SciVal at U of M came from an increased interest in internal expertise and a research activity system that would give a non-financial view of faculty activity. Data entry was a burden with a CV-based system. We learned about commercial options including NIH-Collexis, which NIH was using to find reviewers. The reasons the U of M chose SciVal was because of the significantly lower cost of implementation, lower risk, no runaway IT project, fixed cost, no manual data collection, no faculty involvement, automatic ongoing data collection, no data wranglers, control of the who-wrote-what list, and the ability to download the data with permission.

Implementation was guided by layered value propositions at the macro level (supporting strategic decision making and analysis), the meso level (supporting faculty data infrastructure), and the micro level (supporting collaboration and connection). The combination of all three was an easy institutional support decision. Site traffic is global, with 70% from searches, 30% from links or direct visits.

The value to the faculty is that it makes it easier for faculty to find each other and increases faculty “discoverability” by external user, including external collaborators, potential students, sponsors, and the media. The value to departments and centers is the ability to track publications, working relationships, and research trends. For schools, SciVal helps find experts, engage external contacts, and observe trends, and the data feeds allow for customized analysis and reporting. Across schools, the system improves discoverability.

Mr. Horon then described some use cases for the SciVal application, including finding similar experts for new faculty onboarding, by shortening the “hype cycle” and making the technology lead to productivity faster; supporting conference planning; supporting strategic recruitment decisions; conducting network analysis across the entire institution to reveal strengths, brokers, and collaborators; and targeting RFAs.

Supporting these program applications involves a data gathering challenge at the limit of human scale. Future applications will move beyond medical school (Scopus-based version).

**Questions and Answers**

**Q:** Did you included the SNA information in your P30 application?

**A:** Yes, and it was the only center funded and the PI is convinced that information made an impact.

**Q:** How is data visualized? Is it Excel?

**A:** On demand, egocentric for every researcher and departmental wide network.

**Q:** CV-by-CV, pub-by-pub verification – how long did that take?

**A:** One FTE was our basis for purchasing a hosted solution, so we don’t have to post anything with hard or software support, no maintenance of database. It took 2 temps about 2 months to verify every data point.

**Q:** RDF triples? Do you have interest to move into the Semantic Web?

**A:** The benefits we perceive is that it is discoverable to the outside world and that in turn benefits the faculty because it allows people from the outside world to find us. So yes, we want to expose our data as much as possible.

**Q:** Are you continuing to validate the data moving forward?

**A:** We are bringing the other schools in, and we have heard their data is over 90% accurate, so we trust them. Ongoing maintenance is required because the data are used in tenure and promotion decisions, but it’s on the faculty to make sure their information is correct with the option to correct it themselves. Corrections are held by Elsevier’s team.

**Harvard Catalyst Profiles**

*Griffin Weber, MD, PhD, Harvard Medical School*

*Chief Technology Officer, Harvard Catalyst Profiles*

This application is the same as VIVO in that it uses RDF, but it organizes the front end a little differently and has different analysis and visualizations.

* Active and passive networks
* Keyword cloud with unique areas bolded as potential collaborator
* Topics that change across time through career
* Connection page – why there is a connection made
* Co-author networks: lists, geolocated, egocentric, force-directed graph showing clusters, teams, etc.
* Similar people by key words – people he has worked with before are indicated

Promotion committees and students use this to find mentors or competitors, ego surf, and find department similarities and physical neighbors in a large, multi-site institution. It’s a multidimensional network, not just people, but also departments, facilities, topics, etc. You can look at similar topics, who is working in that topic, what has been published on that topic. You can do SNA, with tools to generate reports and use data in various ways. You can also assess network reach – the correlation between reach and career rank, which varies by department – pathologists collaborate more often. There is also the ability to create a sociograph, which can pull out recommended collaborators to increase your reach graph.

Teams can be anyzed by co-authorship, physical distance, degrees of separation, and MeSH similarity index.

**Questions and Answers**

**Q:** Controlled vocabulary – where does it come from?

**A:** For biomedical, we use MeSH, weights come from data, prevalence, and when they are used more frequently. Outside of biomedicine, it’s not so much about binding ontologies, as we’ve done network analysis of Wikipedia. In other disciplines there isn’t one ontology – there are too many ontologies and have to go to experts and ask which ontology is best. We need to find out where to get publication information and figure out the best terms.

**Q:** Have you investigated Scopus?

**A:** We are talking to a number of commercial vendors and also looking into getting students to type in CVs manually, some data sources have different strengths. Vendors will give you a sample if you give them some data. The best is to find out what data is going to serve or represent your institution the best.

**Research Profiling Networking??? the Loki Perspective**

*David Eichmann, PhD, University of Iowa*

*School of Library and Information Science and Department of Computer Science and Director for Biomedical Informatics, Institute for Clinical and Translational Science Associate*

Dr. Eichmann described himself as a pragmatic heretical visionary. He believes that while we have really excellent tools, they are still first generation tools and not doing everything they should be. Dr. Eichmann described Loki, which was originally conceived as an electronic research interest brochure for Research Week 2006. The organic nature of these platforms is really one of their strengths.

There were 200 faculty who had contributed descriptions, and then we got creeping list of feature requests – can we put publications in? So we rolled in PubMed. Can we see active grants? We did, but then were asked to pull them down because it was a sensitivity point, it’s not that it’s all open data, it’s that putting it all in one place makes you dangerous. Then we started doing the biosketches, then started autopopulating publication lists. It was updated nightly and was a mutable source. We ended up getting a live, direct feed into the sponsored programs funding data base and ran queries directly against their database. It’s a read-only database connection in to IRB, so we know a lot about people on campus and had to beg very little to accomplish it. If you look interesting but not dangerous, things will develop over time. As NIH began to publish their FOA files, we were able to roll that in. Now we had all this data and people decided that we needed to help them get new opportunities. The college of medicine wanted us to build out a CV variation in Loki, but instead we created a unified eCV project and round tripped the data via the rest of the services. An autopopulation of Web of Knowledge citations is in progress, and integration with an institutional repository project is coming soon. Be careful what you wish for because the data is really dirty and we have to pull it down from NIH Reporter. We end up feeding from multiple locations and then mashing it up into a single data base.

There is a Web services API that you can request access to and you can pull down seven figures’ worth of citations, and you have to have separate access to linkages. The library then asks you to help with the institutional repository based on DOIs.

Dr. Eichmann showed a canonical profile page. He expects that investigators will establish their profile up front at their discretion. This issue will become moot soon if it all becomes programmatical. It will become easier with more benefits to participants that way. Unlike other applications, Loki seems to have evolved much more organically.

There are data on 1400 investigators, mostly in medicine, and this was achieved with no marketing, all viral word-of-mouth. Arts and Science, engineering, and the hospitals have an interest in it; even if they have no publication background, they do have a narrative and profile of interest and are involved in clinical trials that aren’t tracked by Loki yet.

We are now looking beyond research networking – Loki is just a component, and it is going to be an integrated ecology. If you get off into nontraditional publications and “scholarly work” then you lose information. If you can bridge to other forms of information, you can expand the benefit and value

We now have CTSA-specific connectivity – annual progress report with a xml file listing all faculty who benefited (eRA commons ID), all of their grants (by award number), and publications (by PubMed number) that benefited from the CTSA. Compliance is a dilemma – Loki is a single screen and all you need to do is check off and then you get to go away – but we still need to get them to log in! We have also interlinked Loki with with IRB electronic review to query whether a universal project ID exist? We know what we know about faculty and never have to ask for it again – which is why faculty like it. We are now looking into using Loki for training opportunity brokerage, research coordinated by work site, and a Kahuna prototype exploiting “gray literature.”

Are research network tools for studying, fostering, or doing team science? I am positing that we are only doing the first. We are fostering team science by brokering relationships, but we are not doing team science. We need to support the entire research lifecycle – all the different use cases where we can make a difference.

**Questions and Answers**

**Q:** Is anyone else using Loki?

**A:** No, it has not been released. We are on version 4.0 but we need to productize it at some point.

**Connecting Institutions to Build a National Biomedical Research Network**

*Maninder (Mini) Kahlon, PhD, University of California, San Francisco*

*Clinical & Translational Sciences, Chief Information Officer & Director, Virtual Home*

Dr. Kahlon explained that when she came back to UCSF and wanted to meet people who were interested in this idea of a national biomedical research network, Collexis was around but it was a different animal. VIVO existed, Profile existed, and if she had to make a choice today it would be hard because there are so many products and so many products overlap and do the same thing. How do you connect all these tools?

Today, many different institutions are using different products. Stanford has their own, and had decided not to make it open source because of their investment, so what can we do to get at that rich data and link it with our own?

This was a team implementation effort, and we launched the pilot in February 2011. There are 29 institutions that did this without any external funding (50,000+ biomedical researchers), and we looked at 8 different networking products. We went beyond the CTSA consortium, included non-CTSA members with the focus on building excitement and trust between institutions. It’s really easy to participate. What we got was basic, but it was enough to get the people to join us. www.direct2experts.org – takes you to the institution and then you enter their particular program. Like Expedia for researchers.

Why a national network? It addresses real needs that require cores, institutional searching of people and resources, research datasets, etc. It’s not easy to identify folks at other institutions who can serve on your DSMB, for example. As a broader example, these programs can find funding opportunities for translational research projects that require collaboration. These programs potentially can address needs we haven’t even thought of yet. The burgeoning world of real-time data and the eagerness of the tool makers to innovate mean that anything is possible.

The status of national networking is that the current solutions use no validated data, they only connect institutions with same project and with not enough specificity. So Dr. Kahlon launched a pilot platform. Her group is not dealing with scale right now, but needs to. They were too popular for our own good. Postdocs will be able to enter their information, so national searches for candidates will be possible in a program called DIRCT. It can be implemented at a single institution and then allow a smooth transition from a local to a national search using same interface.

Institutions can participate by being a source institution, and implement their own search interface (can almost get it “out-of-the-box” at this point), use the network, and join the discussions.

What Dr. Kahlon and her colleagues have done is very simple but it’s just the first step – they are now looking at improving the user interface and finding ways to rank the data and new ways to visualize the results. Another direction will be to focus on scalability – and determine the right technical architecture, whether the data should exposed as part of linked open data. They are also developing a Road Map guide, which is a white paper on how and why to get a tool and what the steps are.

Dr. Kahlon described some strategic issues, such as identifying the balance and role of a centralized service in complementing institutionally-derived data. They also need to ensure that they are not replicating those with much greater resources – Microsoft has something in this space but their data is not the best. They need to integration with and leverage existing trends – so that they are not building the same application to build a CV for example. There is a need to distribute efforts and then share applications. The key is to enable an environment that continues to foster independent innovation – that’s the ultimate goal, not the analysis of the networks.

**Panel Question and Answer Session**

**Q:** When you select collaborators using a tool like this, is there a way to measure the strength of connections between individuals?

**Griffin:** In the profile software there is – the connection pages.

**Q:** Visible path – LinkedIn type program for corporations used email frequency to track who works with who.

**Jeffrey:** Some of the network graphs on the P30 were based on strength-based relationships, co-authors, co-PIs, both, or neither. How many have they worked together how often have they published together?

**David:** In team formation, heterogeneity and enriching the complexity of the result list can be helpful though.

**Mini:** Xobni – can mine your own e-mail to see who you interact with the most.

**Kristi:** We spend a lot of time putting together teams and optimizing relationships so that ultimately the research ecosystem is more than just the people, it’s their resources, skill, efforts, etc. We’ve tried to figure out ways to represent people in the ontology but also other things in the ontology. EagleEye at Harvard is trying to understand the ontology of research resources like equipment, bacterial strains, cell lines, animals, etc. We need to think about researcher networking more than just who, it’s also resources and data.

**David:** One of the things getting bandied about is that the kind of query you can pose gets complicated. If you have to do cross-platform queries, it’s going to get complicated.

**Kristi:** There is a huge trend toward making data available in LOD format – boiling things down to very finite assertions of biological processes and doing things from a Semantic Web approach lets you pull information in a very logical way and very quickly.

**Q:** Can you tease out whether people have already worked on teams?

**Griffin:** We know about certain teams already based on co-authorship and co-funding. If the same people are always working together, they lose benefit.

**David:** Even unsuccessful letters of intent causes things to begin to bubble.

**Q:** We’re not as far along and we keep running into data quality issues. Where can we get good data?

**Mini:** We had no control of the data at UCSF and it was awful. The biggest investment of time for us was getting data, having a good person who understands the organization and environment because there are so many titles to things that make sense – now that we’ve figured it out we’re disseminating the guidelines so the data gets better.

**Jeffery:** It’s a manner of budget and managerial attention to make sure it gets done.

**Griffin:** I still need to go through a huge number of people to use the data for a particular purpose – you need to go through stakeholders first to use the data.

**Holly:** We rallied behind central’s effort for a Faculty and Staff Information System. They realized that the research networking tools could populated the institutional resource systems, and that it was important to have clean data. It took us 22 months to get from the decision to the tool.

**Mini:** We didn’t do it that way, it was hard for us. If there is any level you can move to do it the right way, it is worth it. Things will go much easier once that part is done.

**David:** There is a leadership “me too” factor – if you get enough big institutions, you start hearing, “Why aren’t we doing this?” Costs shift radically at that point.

**Holly:** Once U of I and U of C got it, Northwestern got it.

**Kristi:** It can also happen at a very micro level – people want to see something, so a number of places have put together demo departments, which also allows the data steward to see how the data will be presented. We’ve looked at how to input messy, tabular data at the project mini-grant level.