Enabling Co-Emergent Innovation through Collaboration between Science and Technology Researchers

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AAAS SWARM Meeting
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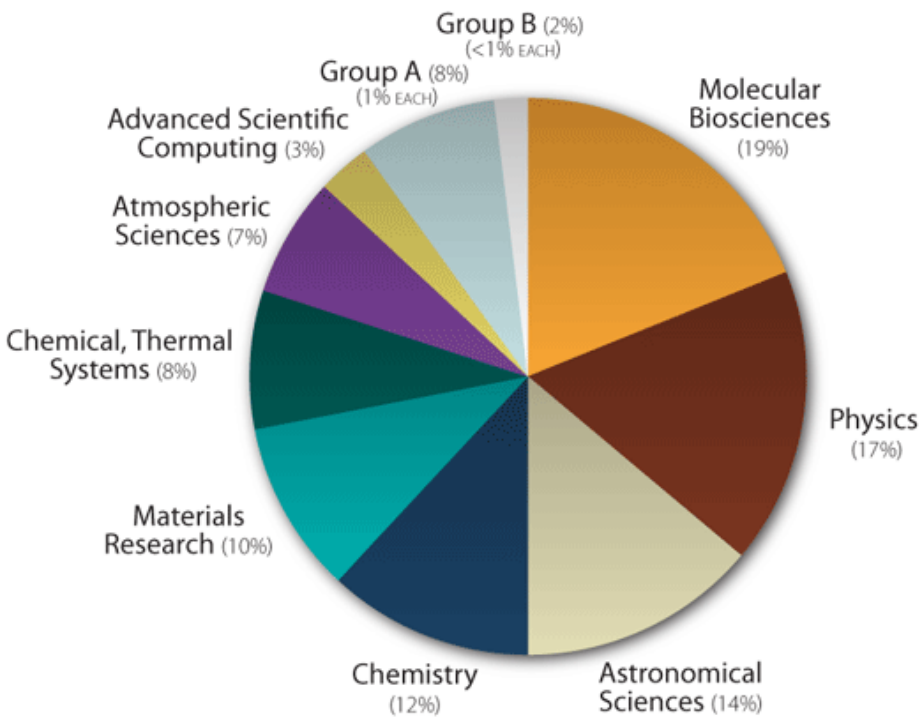
Need

General: Cross-disciplinary, collaborative research teams that can effectively engage in problem solving

Specific: Science & information technology teams

Cyberinfrastructure, eScience, Informatics, Computational science

TeraGrid Allocations
April 2006 (1000 Projects)



Group A (1% each)
Biological and Critical Systems
Computer and Computation Research
Cross-Disciplinary Activities
Earth Sciences
Integrative Biology and Neuroscience
Mathematical Sciences
Mechanical and Structural Systems
Ocean Sciences

Group B (<1% each)
Biological Instrumentation and Resources
Design and Manufacturing Systems
Electrical and Communication Systems
Environmental Biology
Mathematical Sciences
Microelectronic Information Processing Systems
Social and Economic Science
Training

Catlett, C. P. Beckman, D. Skow, and I. Foster (2006). Creating and Operating National-Scale Cyberinfrastructure services. CTWatch Quarterly, May 2006, available online at url http://www.ctwatch.org/quarterly/print.php?p=35.

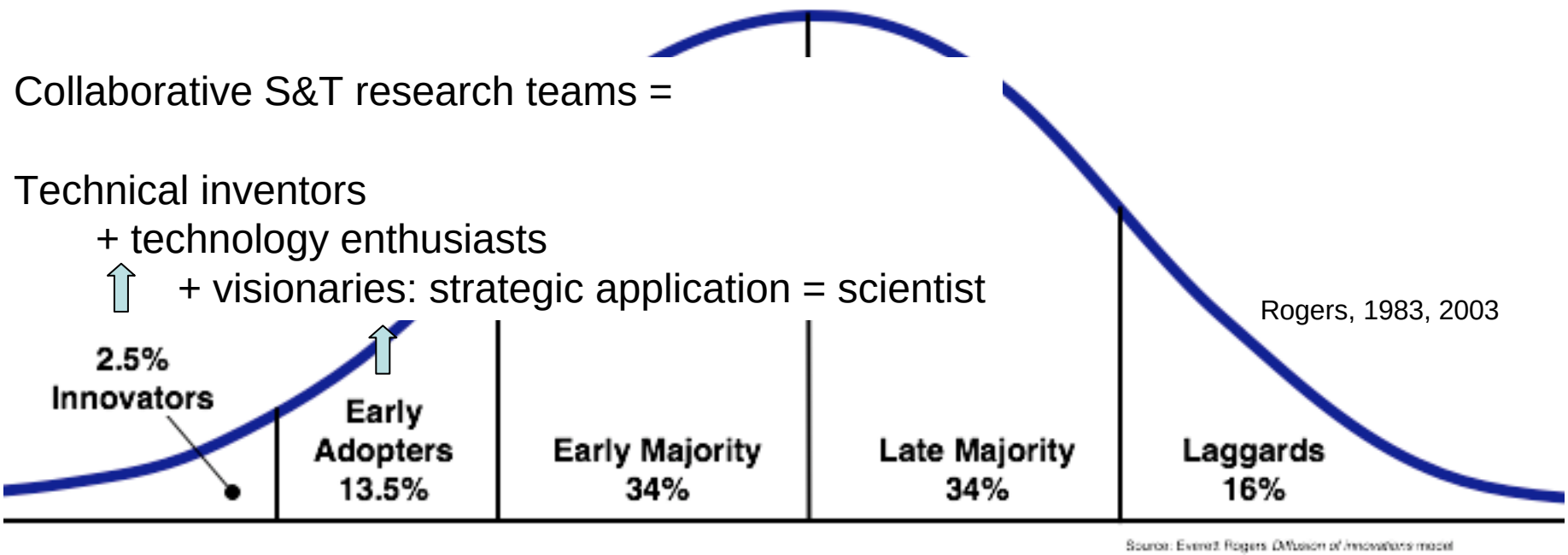
Diffusion of Innovation

Study of how, why, and at what rate new ideas and technology spread through cultures

Collaborative S&T research teams =

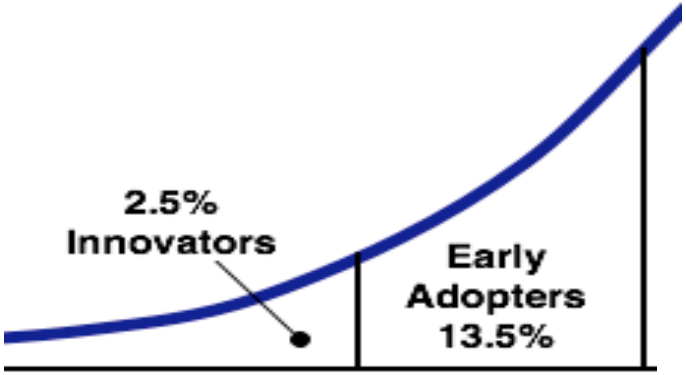
Technical inventors
+ technology enthusiasts
+ visionaries: strategic application = scientist

Rogers, 1983, 2003



Co-emergent innovation

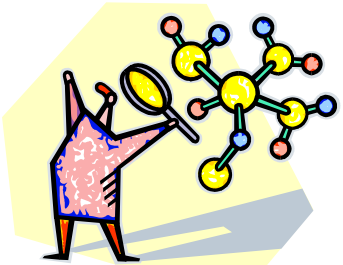
Technical Inventor



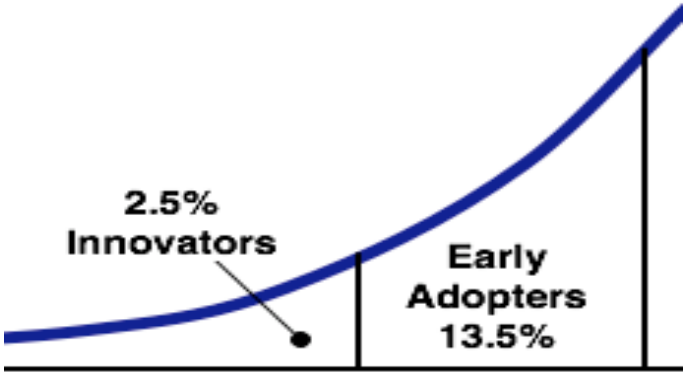
Scientist Early Adopter

Especially problematic where the new technology is disruptive & it is not evident how or why the technology might be useful to this specific scientist

Successful Collaborative Interactions



Scientist Inventor

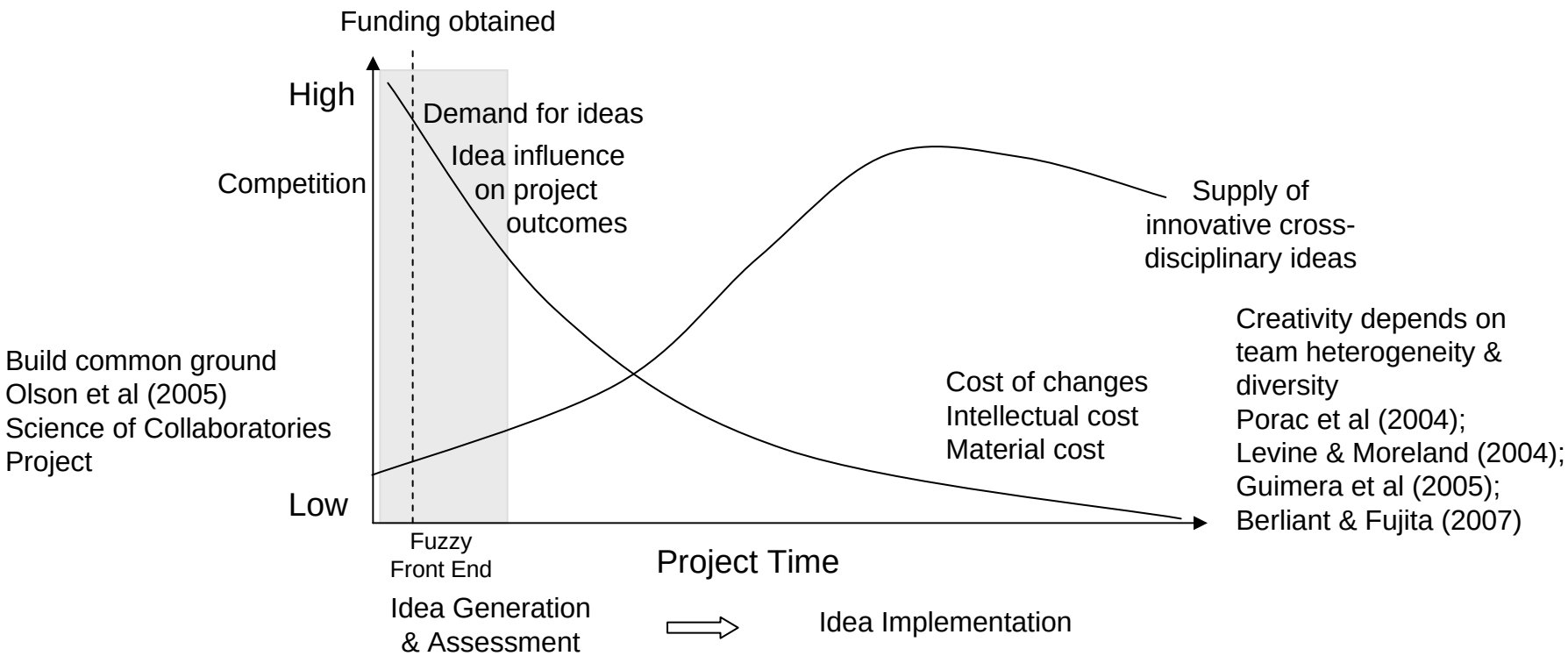


Questions of Interest

How do we enable the matching of research scientists with relevant information scientists?

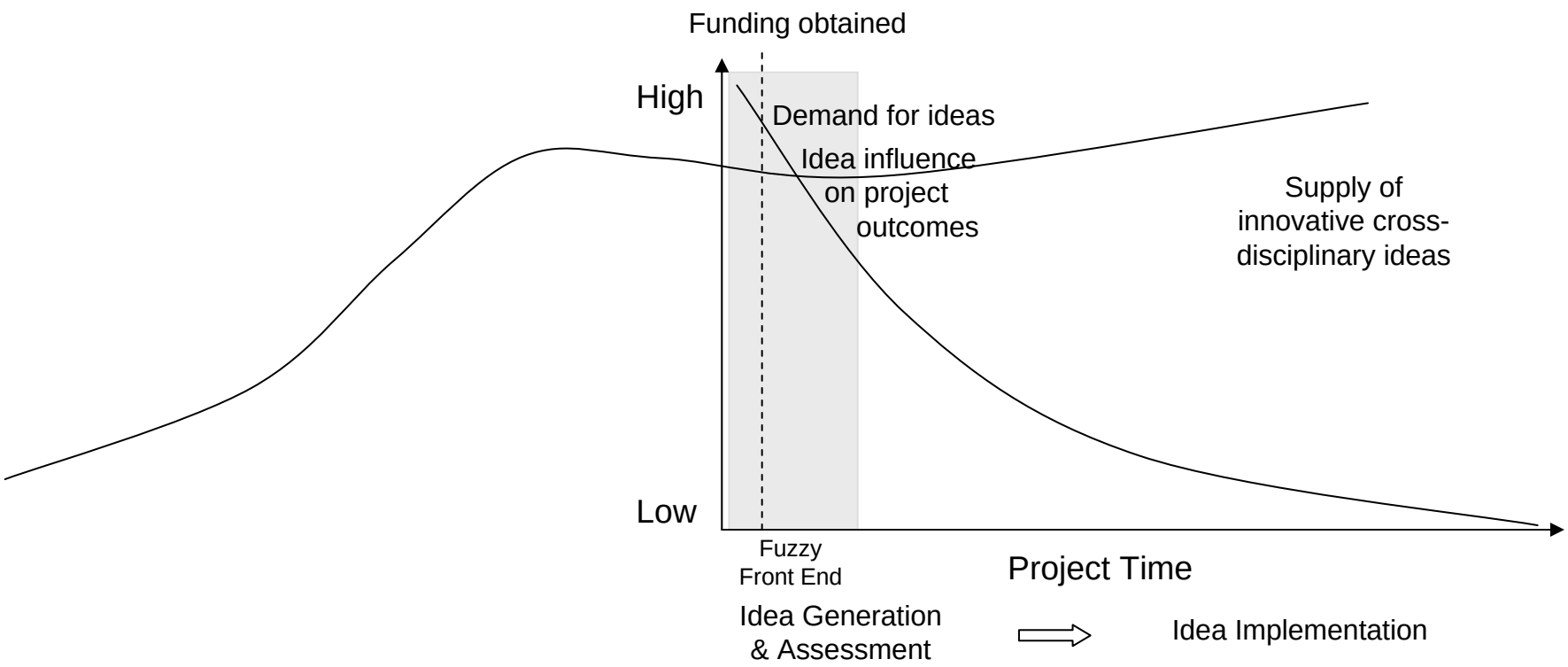
How do we enable collaboration between scientists and computer scientists?

Supply & Demand of Ideas



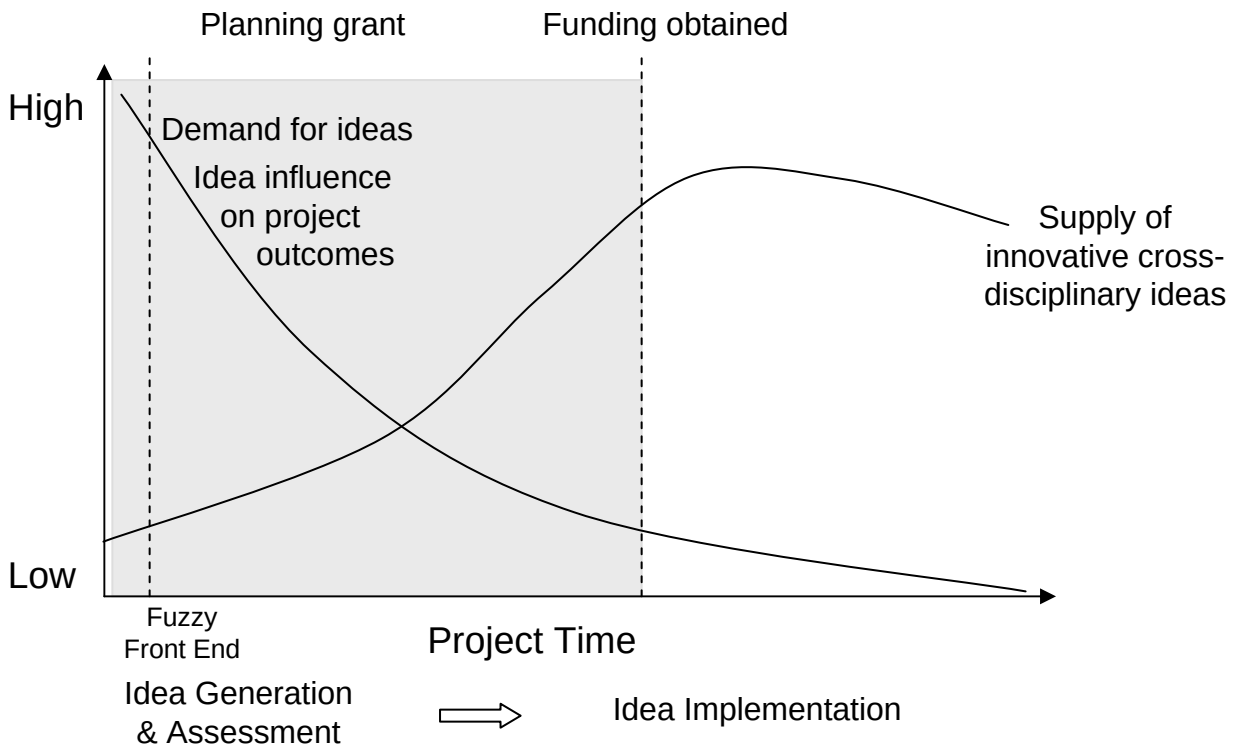
- CI/Technical project design decisions are made before scientists have any clear notion of how the technology might really be useful to them
- Goal alignment gone awry => disjoint research threads
- Results in (at best) sustaining innovation along those threads, but not the desired transformative innovation

Shift the supply of innovative cross-disciplinary ideas earlier in the project



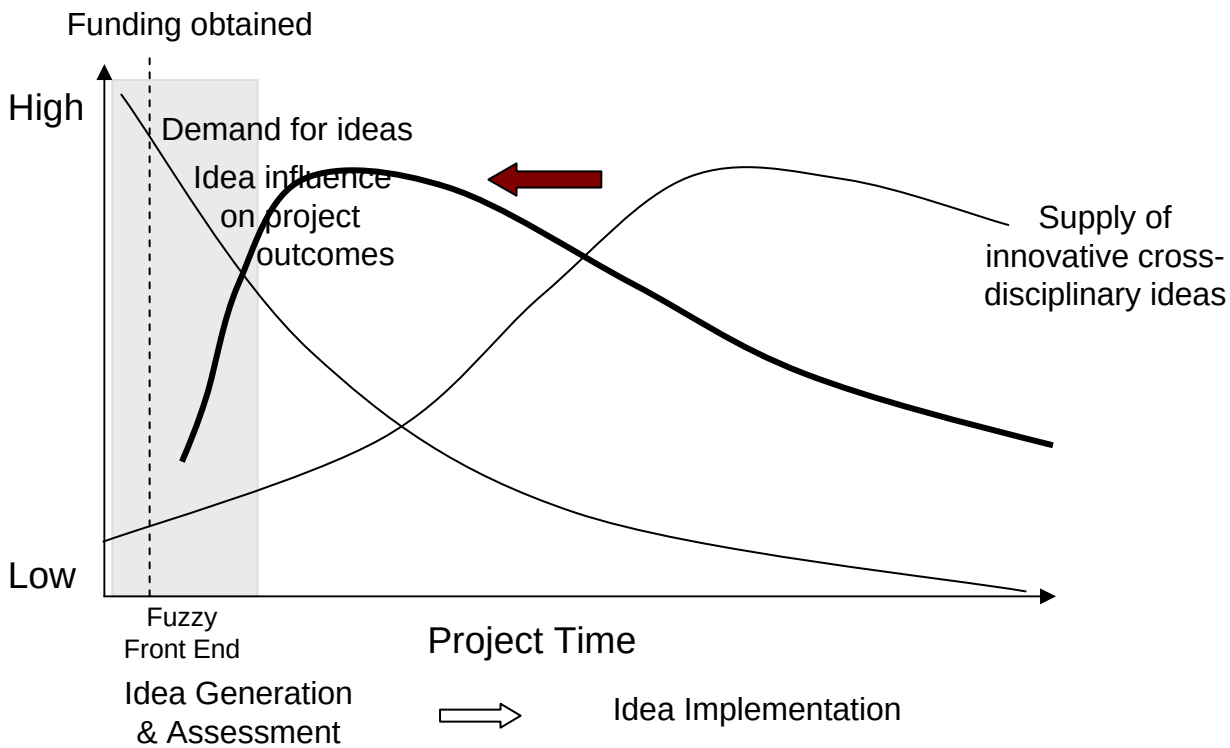
- Use teams who have collaborated successfully previously.
- Add new participants for diversity and hetergeneous perspectives

Shift the supply of innovative cross-disciplinary ideas earlier in the project



•Build planning time into the project (extend the fuzzy front end)

Shift the supply of innovative cross-disciplinary ideas earlier in the project



- **Facilitate the process of idea generation**

SciDesign Project*

Premise: Design of collaborative projects can be enabled by:

- Improving the ability of scientists to perceive the usefulness of new technologies through targeted IT instruction prior to collaboration and build social network of potential collaborators (extended fuzzy front end), and
- Facilitating the idea generation process

NSF OCI #0636317 CI-Team: Advancing Cyberinfrastructure-Based Science through Education, Training, and Mentoring of Science Communities (http://www.scidesign.org)

This research project has been reviewed and approved by the UNM Institutional Review Board (IRB). All investigators have received training in the ethical use and protections of human subjects in research.

Relevant Theory

Goal	Theory	Strategy
Enable the process of organizing	Collaborations are systems, and must be managed as systems (Senge, 1990)	Build linkages between people through facilitated interaction
	The process of collaboration is essentially one of sensemaking, and can be enabled by technology (Weick, 2005; Kirschner 2003)	Use technology to support sensemaking and learning
	Collaboration can be enabled by boundary spanners (Williams, 2002; Levina and Vaast, 2005)	Embed a boundary spanner into the group
	Collaboration can be enabled by boundary objects (Star and Griesemer, 1989)	Construct virtual collaboratory that can both act as a boundary object itself, and also contain boundary objects

Relevant Theory

Goal	Theory	Strategy
Participant Characteristics	Scientists who are likely to be early adopters of technology show a pattern of risk-taking (Rogers, 1962)	Recruit those who have already collaborated with computer scientists to some extent
	Scientists who desire to be cross-trained in technology and bridge the boundary (Rhoten, 2003)	Recruit those who have already demonstrated an interest in the newest technologies
	Scientists and computer scientists who are committed to collaborating as communities of practice (Wenger and Snyder, 2000)	Recruit those who have already worked in problem-based research that crosses disciplinary lines
	Leaders who facilitate and mentor (Senge, 1990), and also engage (Cummings and Kiesler, 2005)	Recruit those who have demonstrated a networked style of leadership

Relevant Theory

Goal	Theory	Strategy
Cognitive, Creative & Learning Processes	Constructivism views learning as a process in which the learner actively builds new concepts based upon current and past knowledge, encoded in a mental schemata (Driscoll, 2005)	Enable rapid construction of schemata for technical concepts through high-level instruction designed to build a comprehensive framework to which details can later be added
	Adults have different learning styles, and the best teaching approach is to incorporate multiple kinds of instruction (Driscoll, 2005)	Each instructional module includes a) explanation of major concepts, b) examples of usage in science, d) demonstration of tool or hands-on activity
	Innovative thinking occurs in individuals when different schemata are juxtaposed (Jeffrey, 2003)	Encourage integration of technical concepts with personal research interests through dialogue and reflection

Relevant Theory

Goal	Theory	Strategy
Shared Vision	Innovative thinking occurs in groups when individual tacit knowledge is made explicit for sharing (Nonaka, 1995)	Employ technical mechanisms for explicit representation of knowledge and sharing of such with group
	The first step to problem solving in groups is to represent the problem in an appropriate, standard way (Voss, 1983)	Employ mechanisms to standardize concept representation, to generate nexus points, and to resolve issues
	Concept maps are an effective representation method for enabling learning (Novak, 2005)	Employ online concept mapping of individual mental models developed above
	Semantic differences must be resolved for cross disciplinary collaboration (Wear, 1999; Bailey, 2001)	Employ technical mechanisms to capture terms from concept maps, create a dictionary and shared taxonomies
	Construction of collective knowledge frameworks facilitates collaboration (Benda, 2002; Bammer, 2005; Boulton 2005; Campbell, 2005; Newell, 2005)	Employ technical mechanisms for Collective knowledge mapping and linkage of concepts with publications with research issues
	Group problem solving is enabled by employing divergent thinking techniques (Jones, 1995)	Use online brainstorming techniques to generate many possible solutions

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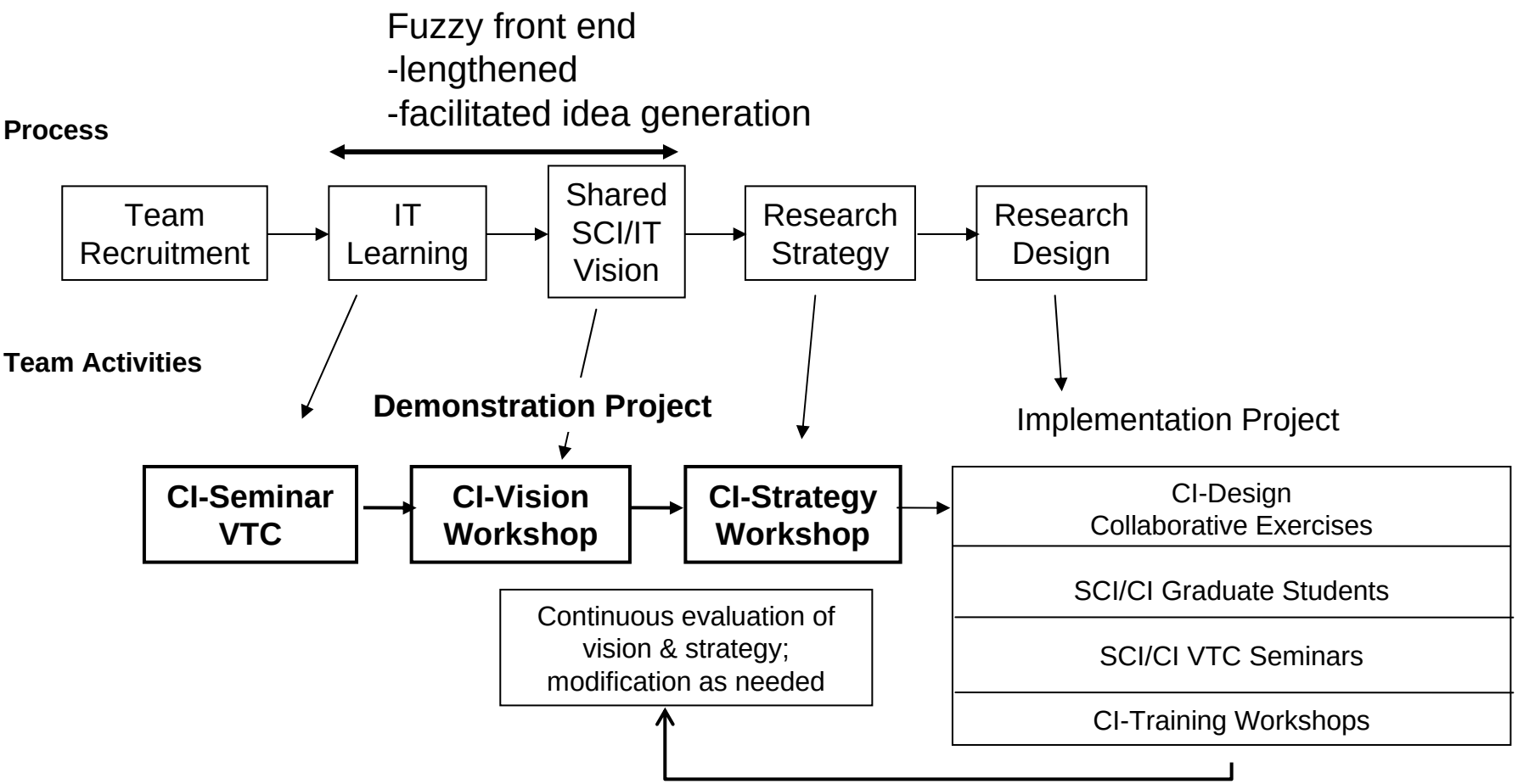

Team Recruitment

No/limited prior collaboration between participants (clean slate)
Willingness to participate without immediate benefit ($$)

Scientists selected based on criteria:

a) Research interests that could be conceptually linked and
    - Related to environmental change
    - In the American Southwest
    - Broad-scale approaches requiring integration
b) An increased likelihood of becoming early adopters of new technologies
    - Technical interest and willingness to collaborate with computer scientists
    - Demonstrated cross-disciplinary collaboration skill

Computer scientists selected based on criteria:

a) Remote speakers: ongoing engagement with domain scientists
b) Initially: Co-located at same institutions as scientists
c) Later: Fit between IT research interests and scientists' needs

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Demonstration Project

CI-Seminar VTC → **CI-Vision Workshop** → **CI-Strategy Workshop**

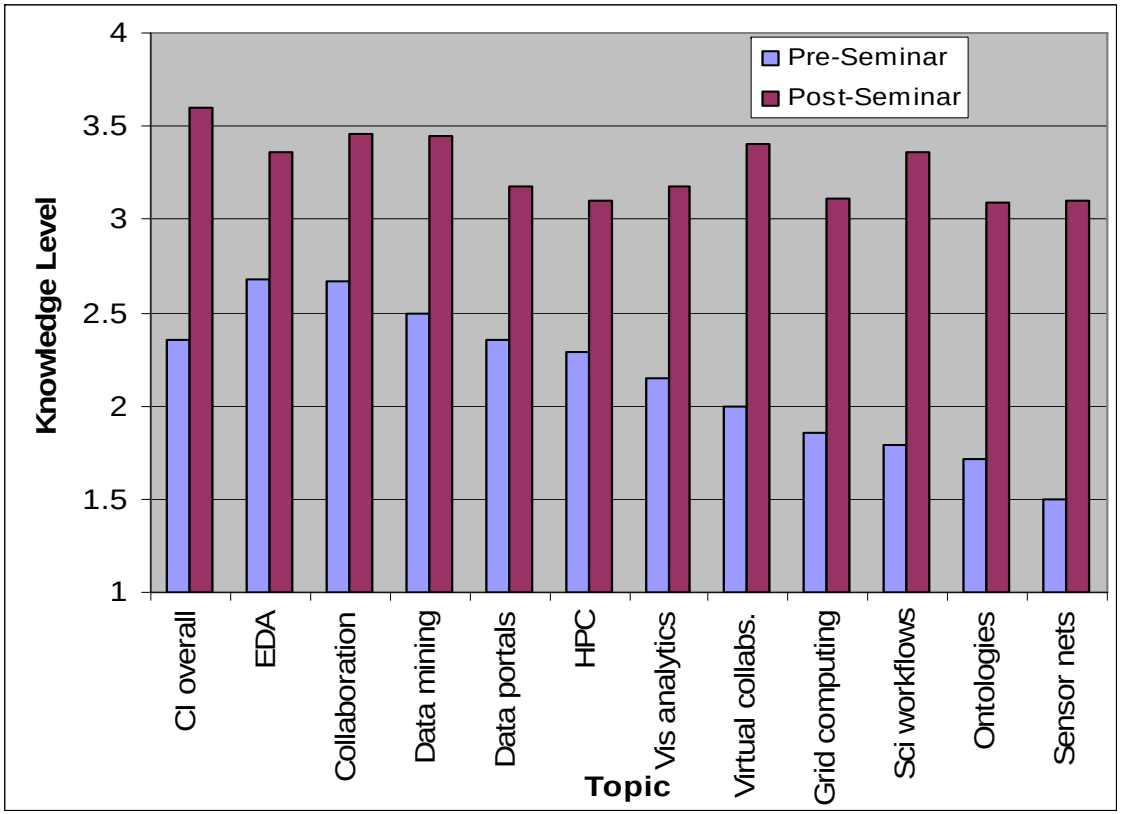
Taught Spring Semester 2007
Synchronous VTC
Remote speakers from CI projects

Topics:

Computation
- Grid computing
- High performance computing

Data, Analysis and Visualization
- Data mining
- Data portals
- Embedded sensor networks
- Scientific workflows
- Ontologies
- Exploratory data analysis
- Visual analytics

Collaboration and Collaboratories
- Collaborative problem solving
- Virtual collaboratories



1 = No working knowledge
4 = High working knowledge

Working knowledge = Basic understanding sufficient to envision use of the technology in your own research

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Demonstration Project

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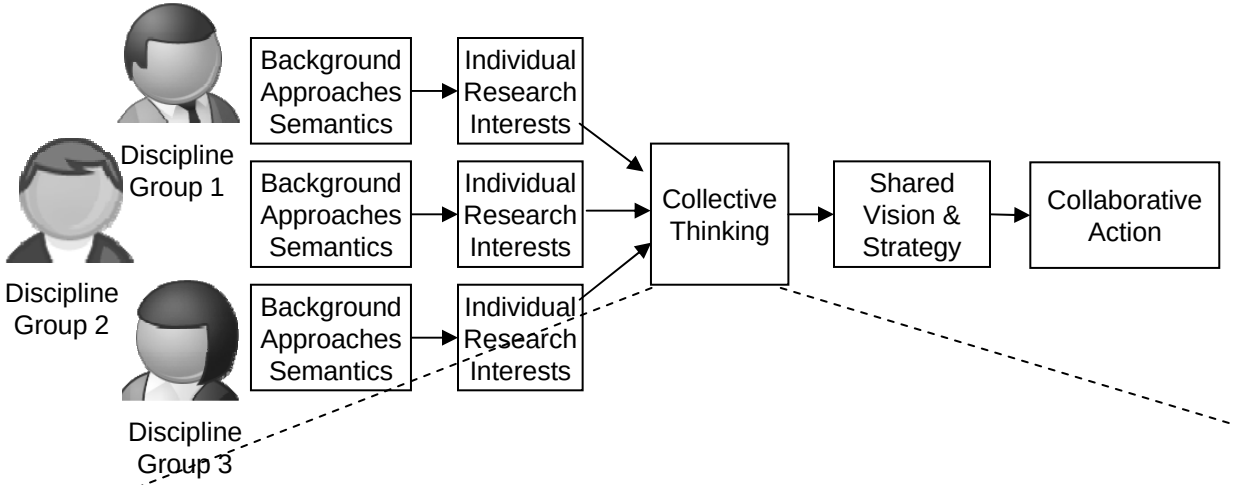
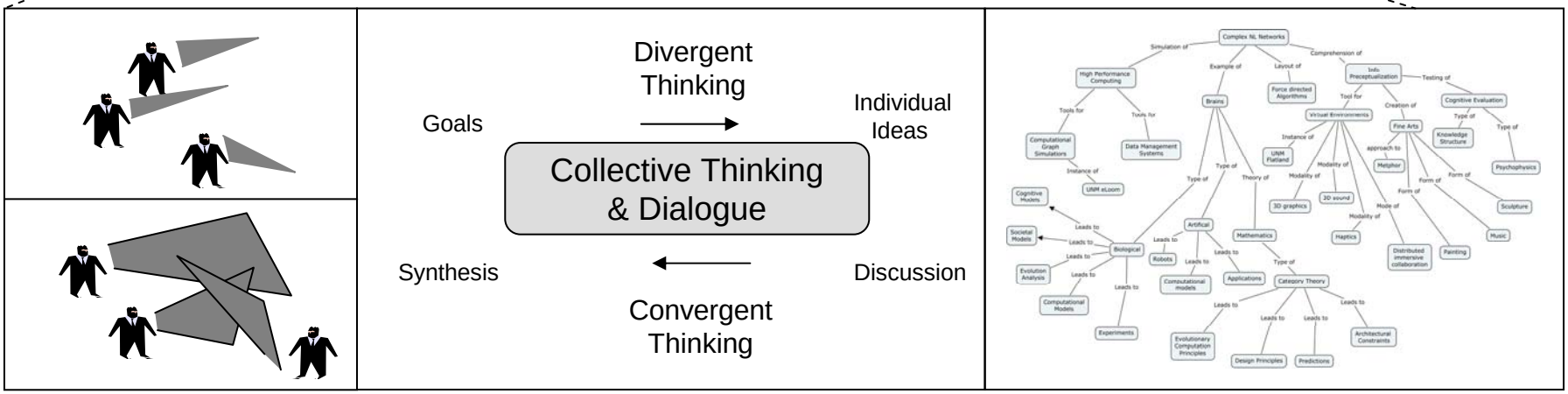
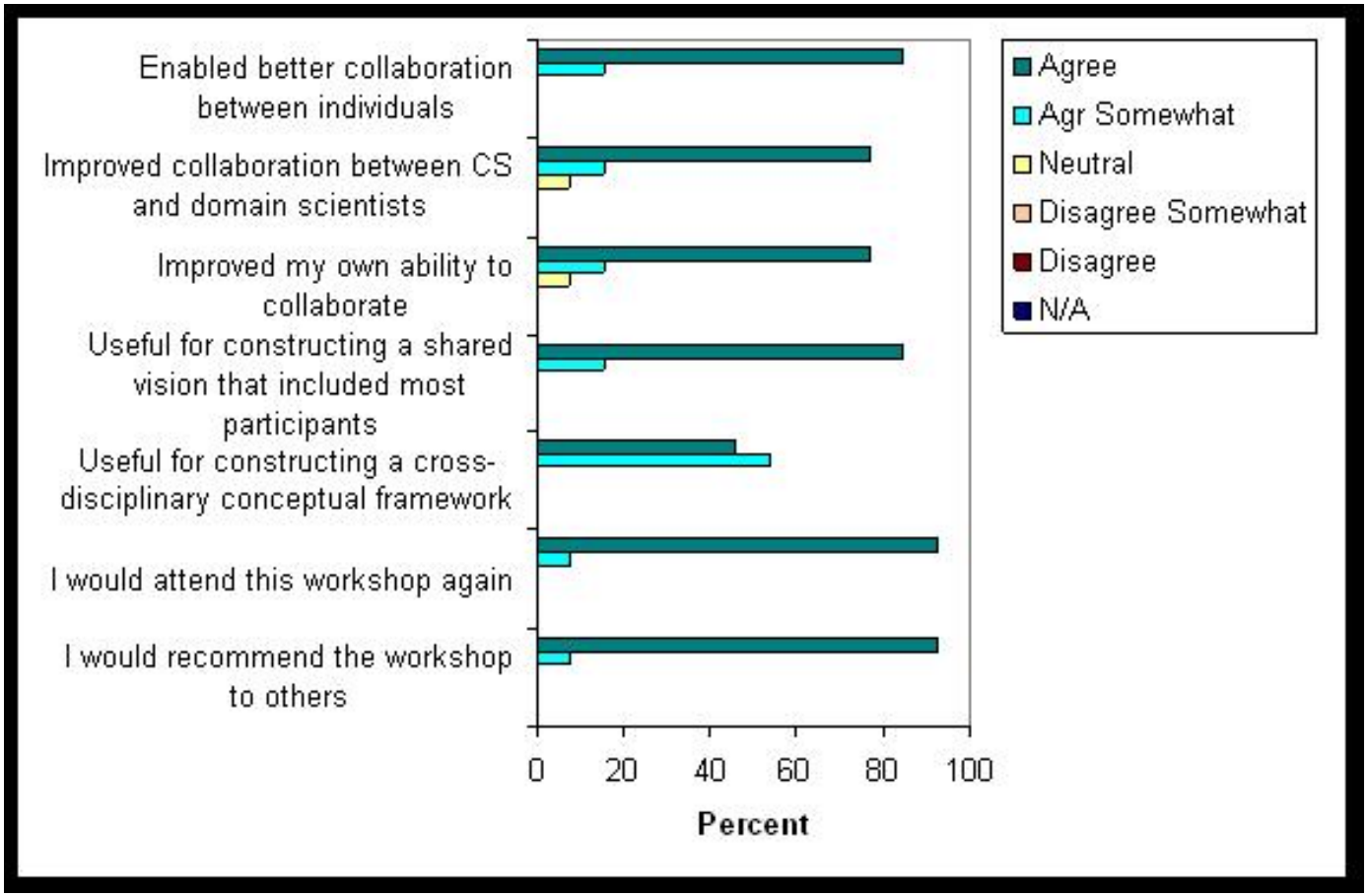




IHMC CmapTools

Survey responses



Survey responses

•**Received primarily positive feedback**. Examples of comments:

"These efforts must be a long-term commitment. This is not an issue that can be resolved adequately in the short-term."
"I really like the fact that it is so peer-to-peer interactive"
"The workshop was engaging the tools used were effective."
"I am thrilled to have been invited and would be so pleased to stay actively within the network."
"Would like to get involved in more of these. Well run and thought out."

•**One central theme was that the visual diagramming (concept mapping) approach was deemed highly useful and extraordinarily effective**.

•**Scientists indicated they could not have had the same level of engagement without the information provided by the seminar**.

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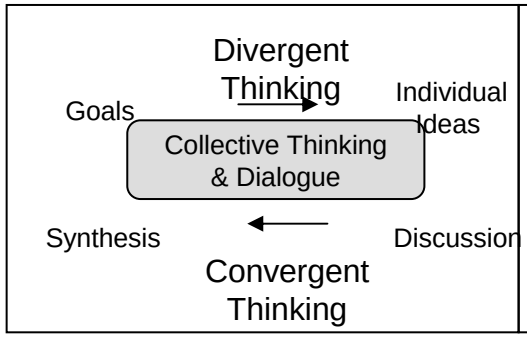
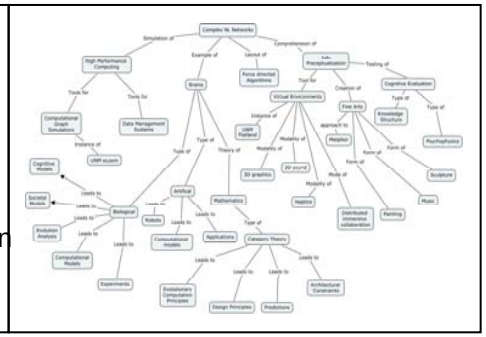
Demonstration Project

CI-Seminar VTC → CI-Vision Workshop → **CI-Strategy Workshop**





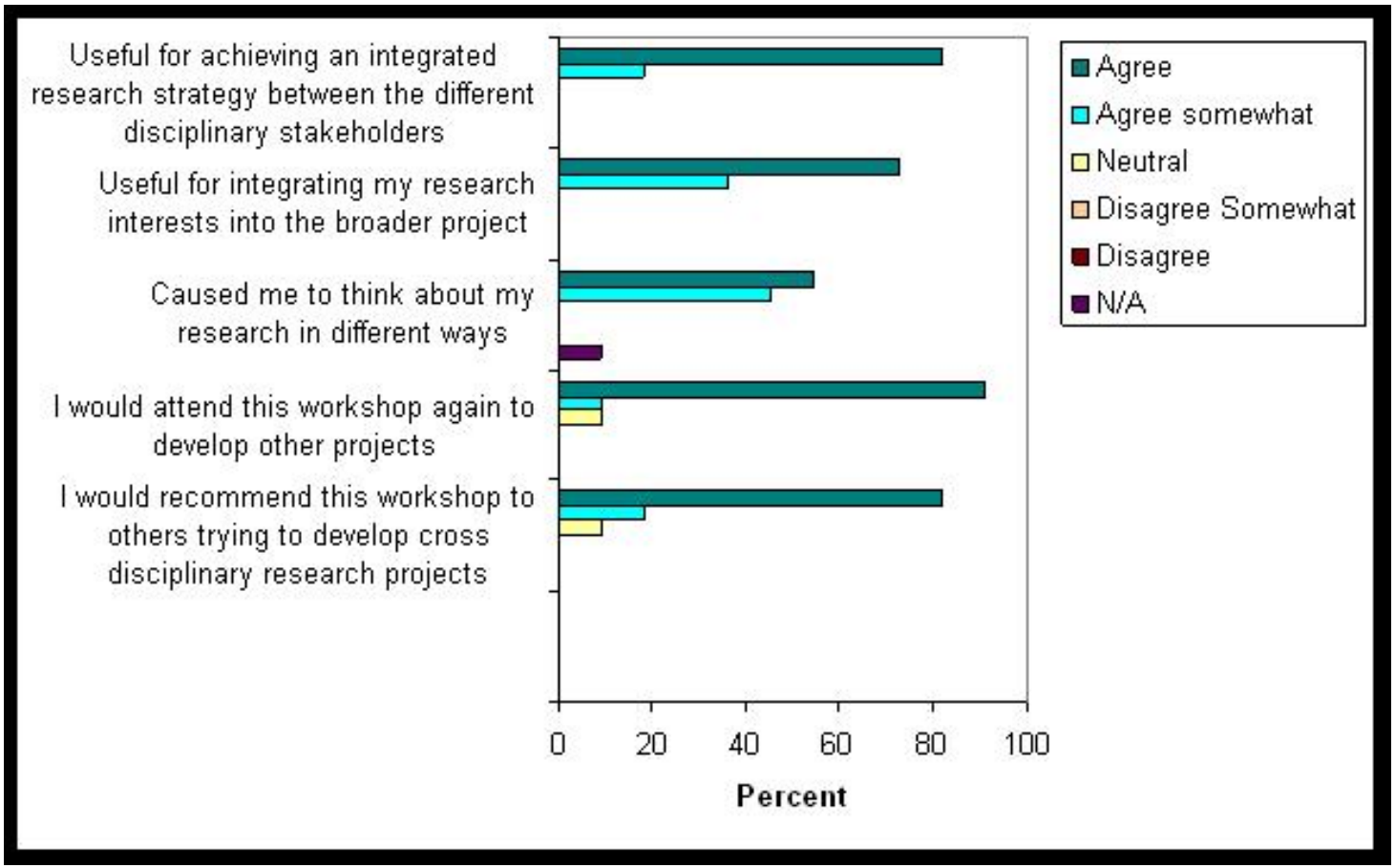
IHMC CmapTools

Different starting place

•CI-Vision individual research interests ➔ articulated shared vision

•CI-Strategy shared vision ➔ articulated 3 collaborative research areas, 3 specific student projects, 2 cross-disciplinary VTC seminars, plus a new idea for teaming up computer science students with the science students

Survey responses



Survey responses

Very positive response. Examples of comments:

“This is one of the very best workshops I've ever attended. It was conducted in a style that caused me to see research connections with scientists from discipline areas that I had never considered before.”

“Again, like in past workshops the diversity of ideas leads to new approaches for me and new ways of thinking about projects.”

“Definitely got all parties involved and contributing to the discussion. Discussions evolved and people built on other participant's ideas.”

“Low pressure, a chance to think, bottom up, incremental.”

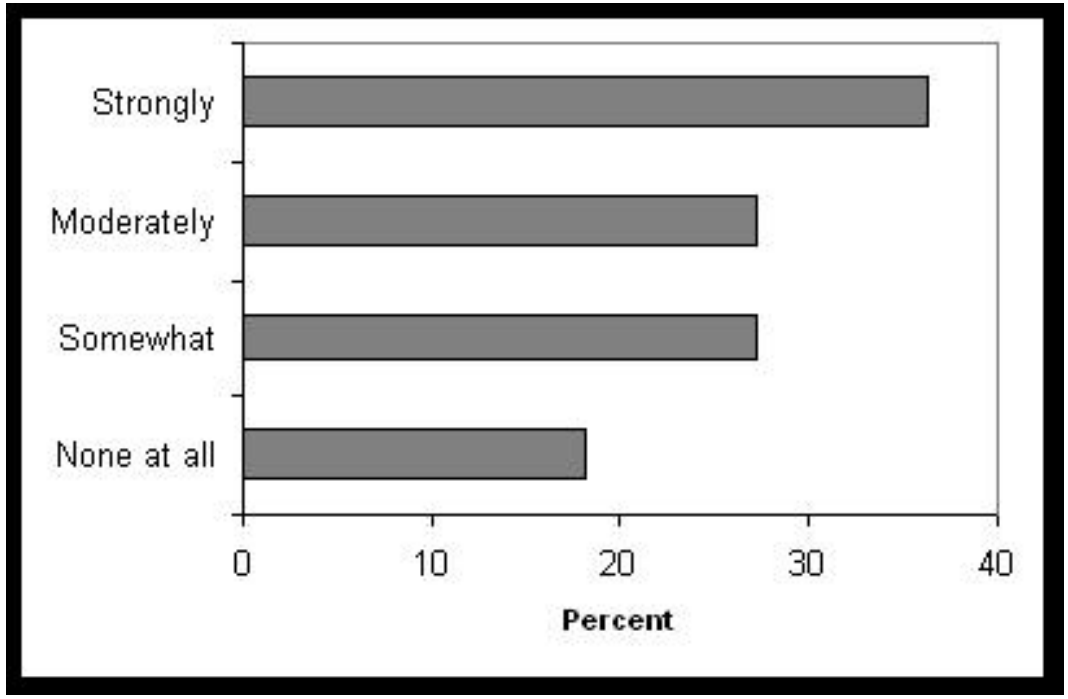
Evaluation of overall process

- Are they able to articulate innovative, fundable, collaborative research?
- Has their cross-disciplinary understanding improved?
- Do they have the social network in place to build a cross-disciplinary collaboration?

***Key: how do outcomes differ from a control group without the process?
•Controlled experiment (not feasible)
•Compared against existing collaborations (but what short-term measures)

Survey response

To what degree is the project influencing the direction of your research interests?



Survey response

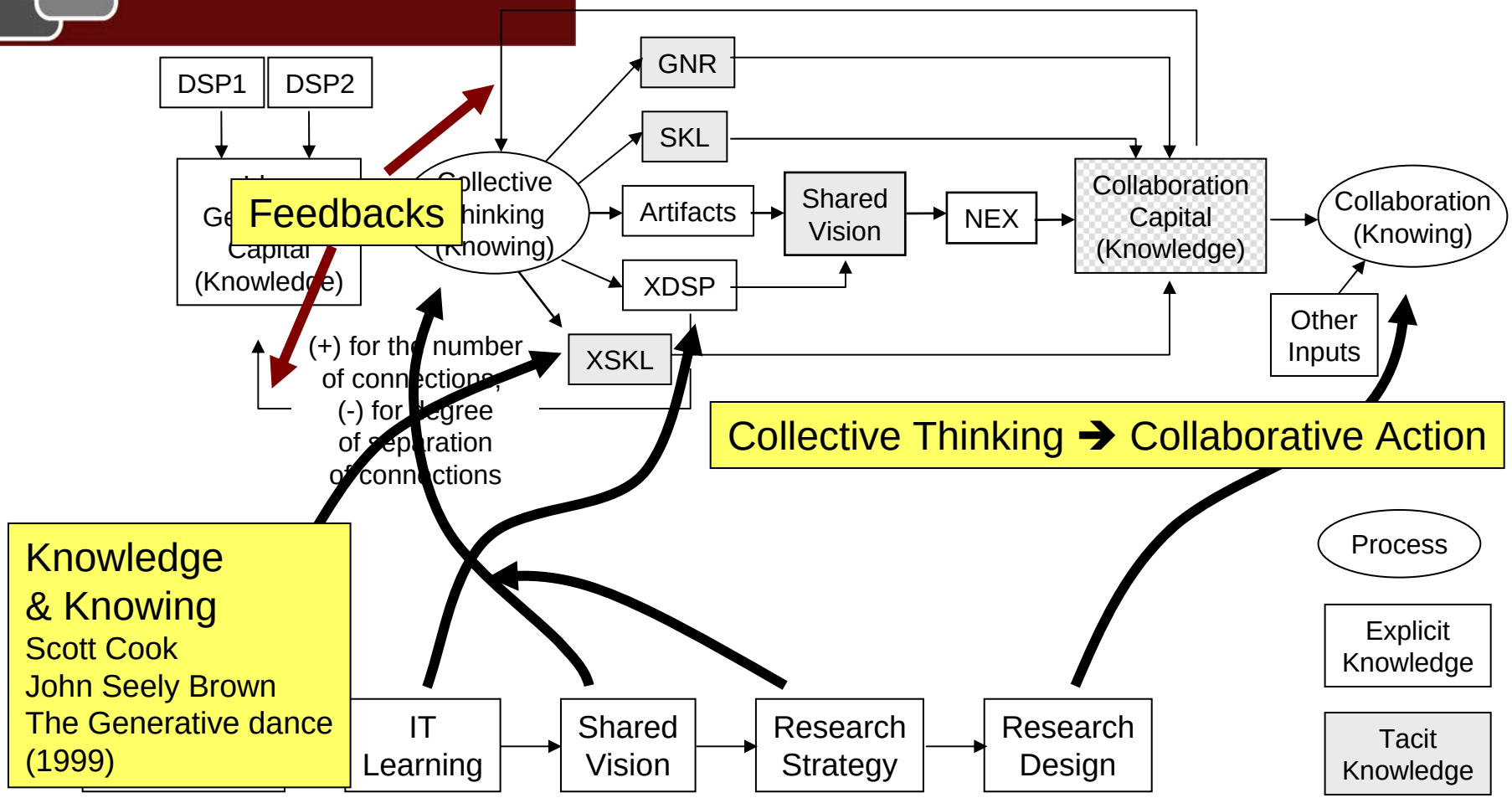
The process is improving their ability to think collectively across disciplines.

- "Talking and listening to other scientists, learning about their research led to a number of 'aha!' moments where I saw opportunities for collaboration."
- "The fusion of different views was for me an epiphany."
- "Different perspectives and active engagement by everyone trying to make connections was key."
- "Caused me to see research connections with scientists from discipline areas that I had never considered before."
- [Participant particularly likes]…"the mix of researchers and ideas. Interactive discussion, refinement and consensus. "
- "Getting researchers together to do cross-disciplinary is extremely challenging. Sometimes it's obvious how two disciplines might fit together but more often discipline specific language, culture and mindsets keep broad thinking from happening."

The process is leading to innovative research ideas.

- "Introduction of new views and perspectives on areas that I work in [are] already producing new insights."
- "The diversity of ideas leads to new approaches for me and new ways of thinking about projects."
- "I was exposed to new concepts…that will completely transform my research. For example…[participant description of new approach being planned]. Additionally, a new direction I am considering…[another participant description]. I would not have considered that at this point without having participated"

Collaboration Model



Does manipulation of these factors result in “better” collaborative outcomes?

Conclusions

- It is possible to design interactions between scientists and technologists that improve the likelihood of innovative outcomes for both
- These interactions must be intentional. The process is structured while the content is emergent
- They require lead time preparing participants for their first meeting
- Biggest issue is participation – motivating factors when benefits are not immediate

Acknowledgements

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- **Science collaborators:** Gary Christopherson (U Arizona), Neil Cobb (Northern Arizona U), Gregg Garfin (U Arizona), Lou Scuderi (U New Mexico), Wim van Leeuwen (U Arizona), John Vande Castle (U New Mexico), Steve Yool (U Arizona),
- **Students:** Wolfgang Grunberg (U Arizona), Crystal Krause (Northern Arizona U), Lezlie Moriniere (U Arizona), Aaryn Olsson (U Arizona), Andy Yuhas (U New Mexico)
- **Computer science & informatics collaborators:** Jim Beach (U Kansas), Thomas Caudell (U New Mexico), Jeannine Cook (New Mexico State U), Eck Doerry (Northern Arizona U), Dan Li (Northern Arizona U), Lorie Liebrock (NM Tech), Barney Maccabe (U New Mexico), James Palmer (Northern Arizona U), Mark Servilla (U New Mexico), Aimee Stewart (U Kansas), Pat Teller (U Texas El Paso), Tim Thomas (U New Mexico)
- **Remote presenters**: Allen (U California Riverside), Arzberger (U California SD), Baru (San Diego Supercomputer Center), Cook – (NM State U), Collins (U New Mexico), Doerry (Northern Arizona U), Downey (U New Mexico), Dunston (NM Tech), Fountain (San Diego Supercomputer Center), Fox (U Corp Atmospheric Research), Gahegan (Penn State U), Jones (Natl Center Ecol Analysis and Synthesis), Keller (U Oklahoma), Kooper (Natl Center Supercomputing Apps), Kratz (U Wisconsin), Kumar (Natl Center Supercomputing Apps), Liebrock NM Tech), Maccabe (U New Mexico), Maden (Natl Cen Ecol Analysis and Synthesis), McGuinness (Stanford U), Minsker (U Illinois UC), Myers (Natl Center Supercomputing Apps), Salisbury (U New Mexico), Servilla (U New Mexico), Teller U Texas El Paso), Thomas (National Center Visual Analytics), Villa (U Vermont), Zimmerman (U Michigan)
- **A great team to work with!**

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- Questions?