INTERDISCIPLINARY TEAM SCIENCE

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MY TASK

- What is *interdisciplinary* team science?
- Why is it *challenging*?
- What are some *evidence-based* methods for enabling it?
- A practical *example*

WHAT IS TEAM SCIENCE? VOCABULARY PT 1

- ***Team science***: Collaborative, often ***cross-disciplinary*** approaches to research on a particular topic.
- ***Cross-disciplinary***: Includes perspectives from two or more disciplines. Includes ***multidisciplinary, interdisciplinary, and transdisciplinary***

- ***Multidisciplinary, interdisciplinary, and transdisciplinary:*** Used in different ways

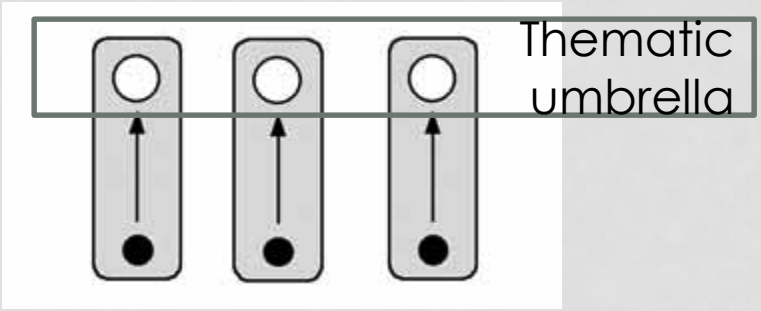
WHAT IS TEAM SCIENCE? VOCABULARY PT 2

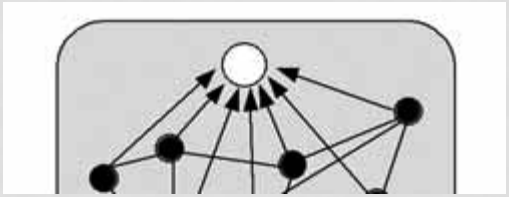
Researcher

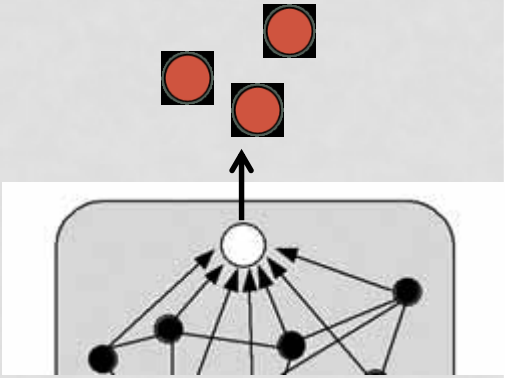
Research goal

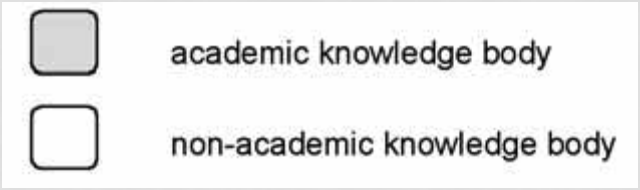
Research frameworks

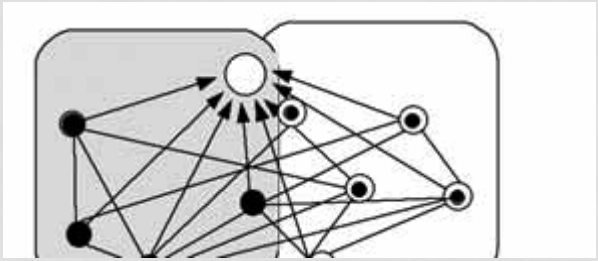
- Disciplinary
- Multidisciplinary
- Interdisciplinary
- Transdisciplinary











"Convergence"

Tress, Tress & Fry 2002

EXAMPLE: BIOINFORMATICS

- Multidisciplinary Genomics + Data Mining
- Interdisciplinary Bioinformatics analyses
- Transdisciplinary Bioinformatics community

Evolutionary, developmental process
Start multidisciplinary => interdisciplinary

IS-GEO

- Multidisciplinary
  - Our goal: **we are starting here**. Need to focus on learning each others' methods, finding commonalities, and finding new areas to explore.
  - Example: Hyperspectral data mining in 2001 and theory-driven machine learning
- Interdisciplinary
  - Our goal: identify some **key problems that link** research on both sides.
  - Example: Scientists as data and problem providers; intelligent system specialists as programmers
- Transdisciplinary
  - Our goal: Translation of research findings to **practical, working cyberinfrastructure.**
  - Example: IS that are credible, salient, and legitimate

CREDIBLE, LEGITIMATE, SALIENT

- Credible: peer-reviewed, tested rigorously - goal of academic research
- Salience: relevance to users.
  - Must solve a perceived problem.
- *Legitimate: fairness to a variety of actors – does it fairly represent research perspectives that are truly IS-GEO?
  - Scientists as data and problem providers; computer specialists as programmers
  - Discuss this – big problem (5 min)

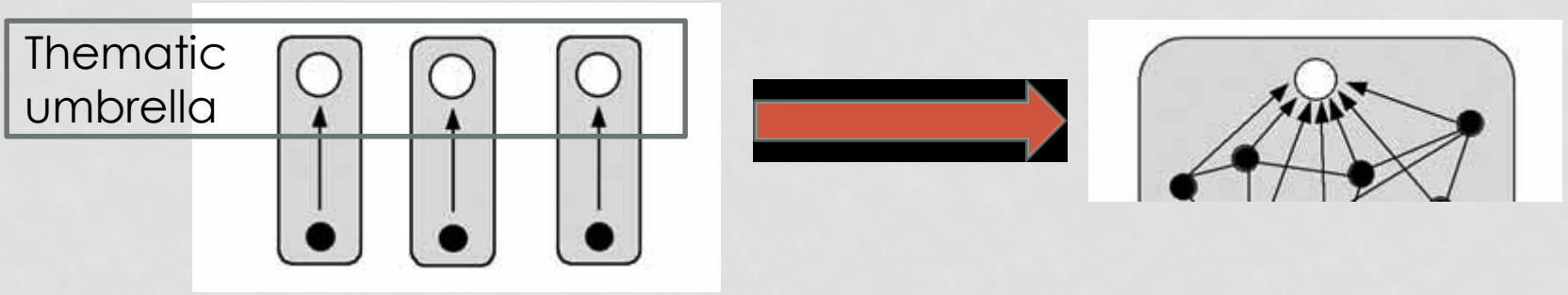
INTERDISCIPLINARY RESEARCH IS CHALLENGING

- Show of hands….
- Anecdotal evidence: many large complex research teams are taking 1.5-3 years to figure out how they can work productively together
- Those are the success stories. Many others fail to ever find a way to work together productively
- Science of Team Science community: studies of these teams as complex systems in and of themselves

WHY SO DIFFICULT?

MULTIDISCIPLINARY

INTERDISCIPLINARY



5 minutes: At your table, list reasons

STOKOLS ET AL. (2008) FACTORS

Table 2. Key contextual factors that influence transdisciplinary team effectiveness at each level of analysis

Intrapersonal	Interpersonal	Organizational/institutional	Physical/environmental	Technologic	Sociopolitical
Members' attitudes and values during the formation of a transdisciplinary collaboration, such as valuing collaboration, supporting a culture of sharing, embracing a transdisciplinary ethic, and sharing egalitarian values Members' collaborative readiness in terms of their openness to other disciplinary perspectives; willingness to devote large amounts time and effort to building personal relationships; and preparedness for the uncertainties, tensions, and complexities inherent in transdisciplinary teamwork Members' collaborative experiences with each other on earlier projects Presence of exemplary leaders who are empowering, inclusive, and transformational; a participatory leadership style that enables all members to play an active role in team goal-setting and decision-making activities	Regular and effective social and intellectual communications to establish common ground, overcome task-related uncertainties, and develop consensus around a shared vision and collective goals Diversity of members' knowledge and skills Members' ability to learn about each other's expertise and create a hospitable conversational space Mutual respect among team members Members' familiarity and social cohesiveness, coupled with their ability to adapt flexibly to changing circumstances, remain open to new perspectives, and challenge existing assumptions and procedures	Presence of strong organizational incentives to encourage participation and sustain collaborative orientation among members Broad-based institutional support for intradepartmental and inter-university collaboration through modifications of organizational structures and administrative routines (e.g., merit and promotion procedures in academic settings) Nonhierarchic arrangements that provide autonomy to team members and encourage participatory goal setting and decision making Breadth of disciplinary perspectives represented among team members Scheduling of retreats and informal social events to encourage informal contact and communication among members Assurances of long-term support by funding agencies so that teams have more time to establish trust, build relationships, and accomplish their goals	Spatial proximity of team members' offices and laboratories to encourage informal contact and communication Availability of comfortable meeting areas for group discussion and brainstorming activities Access to distraction-free work spaces for individualized tasks requiring concentration, confidentiality, or both Physical environments that support members' efforts to regulate their interpersonal privacy and accessibility to others over the course of their collaboration	An organization's technologic infrastructure readiness, or access to necessary bandwidth, electronic networking capabilities, linkages between sites, and technical support for remote collaboration Provisions for high-level data security, integrity, privacy, rapid retrieval, and long-term archival access, and technologies that facilitate the formation of knowledge and social networks Members' technologic readiness, including their knowledge of and familiarity with various electronic information and communication tools, protocols, codes of conduct for distance collaboration, and the effectiveness of their communication styles	Easing of international tensions through cooperative policies that encourage exchanges of scientific information and transdisciplinary collaboration among scientists from different regions of the world Enacting policies and protocols to support effective transdisciplinary collaboration, such as those ensuring ethical scientific conduct and management of intellectual property ownership and licensing Occurrences of adverse global environmental changes and public health problems that prompt intersectoral and international transdisciplinary collaboration in scientific research and training programs

ALL TEAMS STOKOLS ET AL. (2008)

- Presence of exemplary leaders who are empowering, inclusive, transformational, and have a participatory leadership style,
- Members ability to learn about each others' expertise,
- Regular and effective communication to establish common ground, overcome task-related uncertainties, and develop consensus around a shared vision and collective goals, and
- Team flexibility and adaptability

CHALLENGES OF TEAM SCIENCE

National Academy of Sciences (2015) Enhancing the Effectiveness of Team Science

1. High diversity
2. Deep knowledge integration
3. Large size
4. Goal misalignment
5. Permeable boundaries
6. Geographic dispersion
7. Task interdependence

INTERPERSONAL FACTORS

CHALLENGES OF TEAM SCIENCE

High diversity

Focus here

Deep knowledge integration is difficult

Goal misalignment

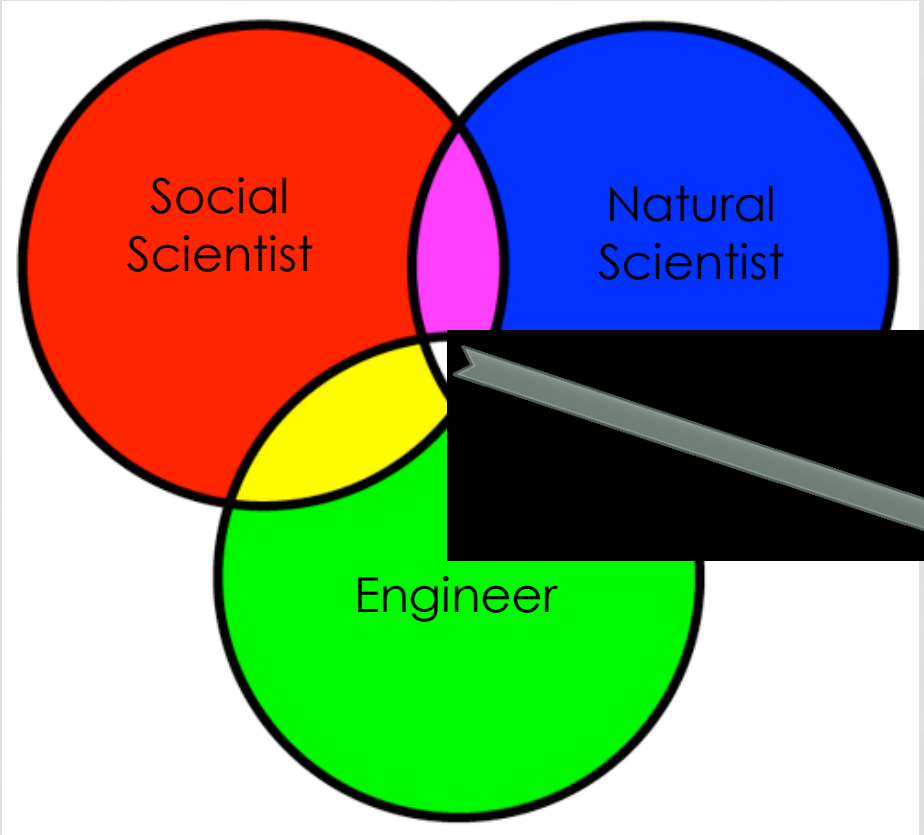
Task interdependence mistakes

"Vote with their feet" through permeable boundaries

Exacerbated in large, dispersed teams

DISCIPLINARY TRAINING

Different cultures:
Ways of working
Methods
Data types
Values
Motivations
Epistemologies
Uncertainty tolerance
Etc.



Different knowledge:
Freshman/ Sophomore Core Curriculum

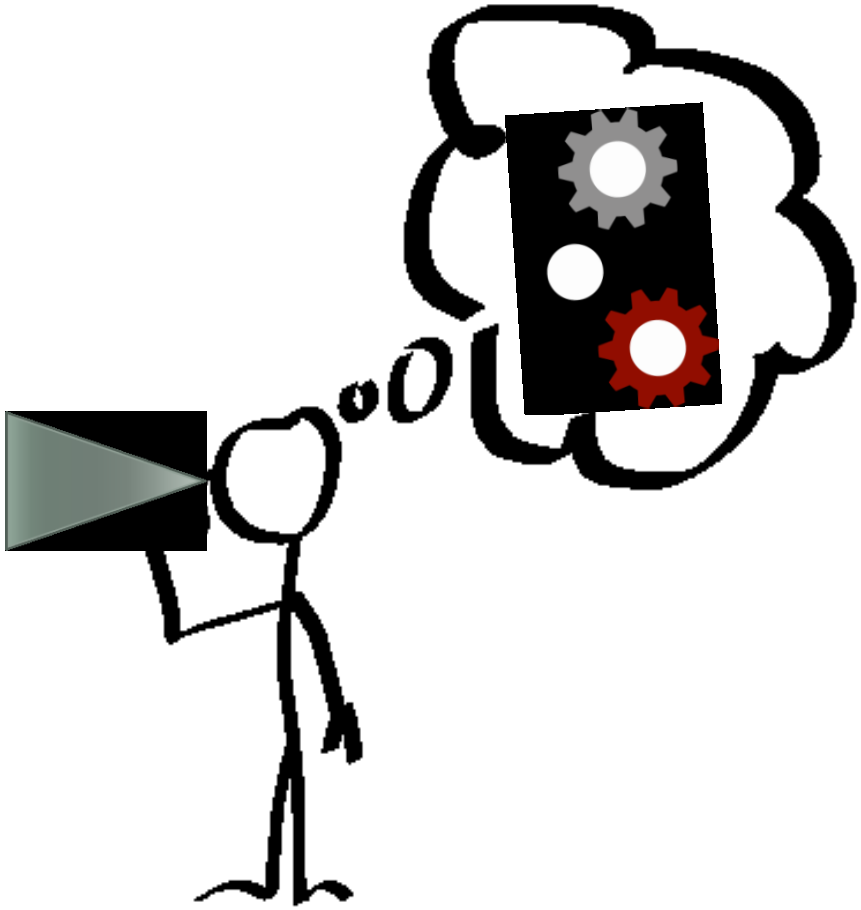
LEARNING & CONSTRUCTIVISM

Constructivism: learner actively builds new concepts based upon current and past experiences, encoded in a ***mental model***

Experts have extensive mental models around their area of expertise and are able to reason with them in ways that differ from novices

MENTAL MODELS

Real v
phenon



Our minds are rather messy places!

EXPLAINING PERSPECTIVES

Communication issues:

Explainer:

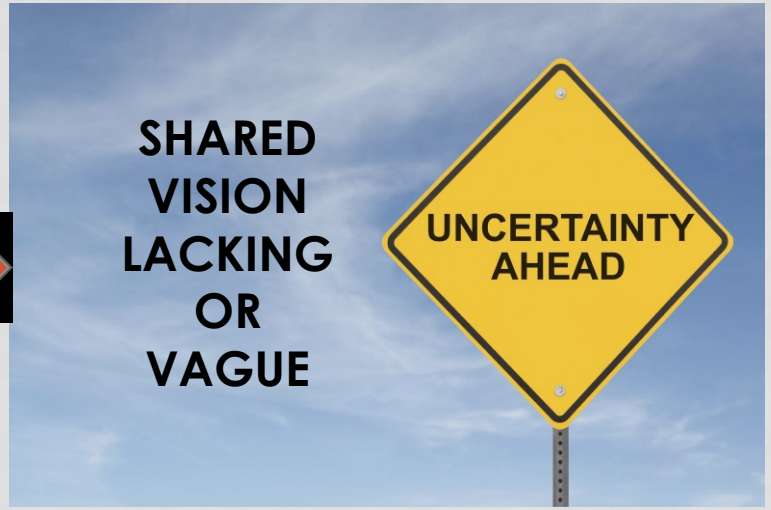
- Deep knowledge
- Research frontiers
- Difficult to simplify
- Difficult to represent

Learner:

- Lack of foundational concepts
- Jargon unknown
- No comparable mental model
- No perceived connections to their own knowledge

ILL-DEFINED PROBLEMS
A.K.A. WICKED PROBLEMS

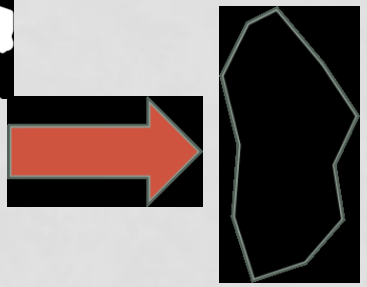
MENTAL MODELS OF THE PROBLEM



DISFUNCTIONAL TEAMS: "FAILURE TO THRIVE"

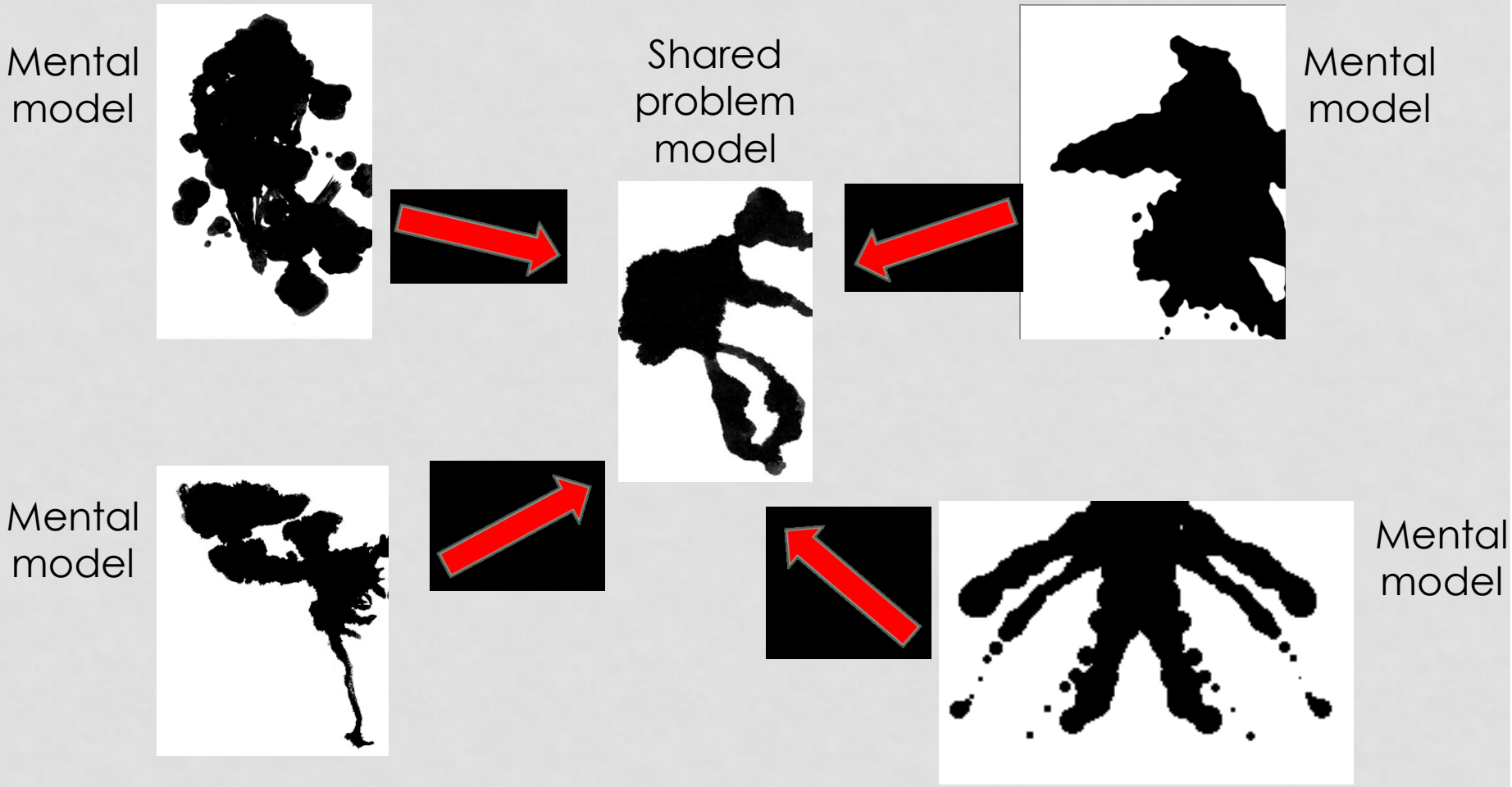
What is my role? ? ?
How is this research for me?
?

I am out of here…
Taking my funding and going back to my own lab



SHARED VISION

SHARED PROBLEM MODEL



Fiore (2004); Pennington et al. (2016)

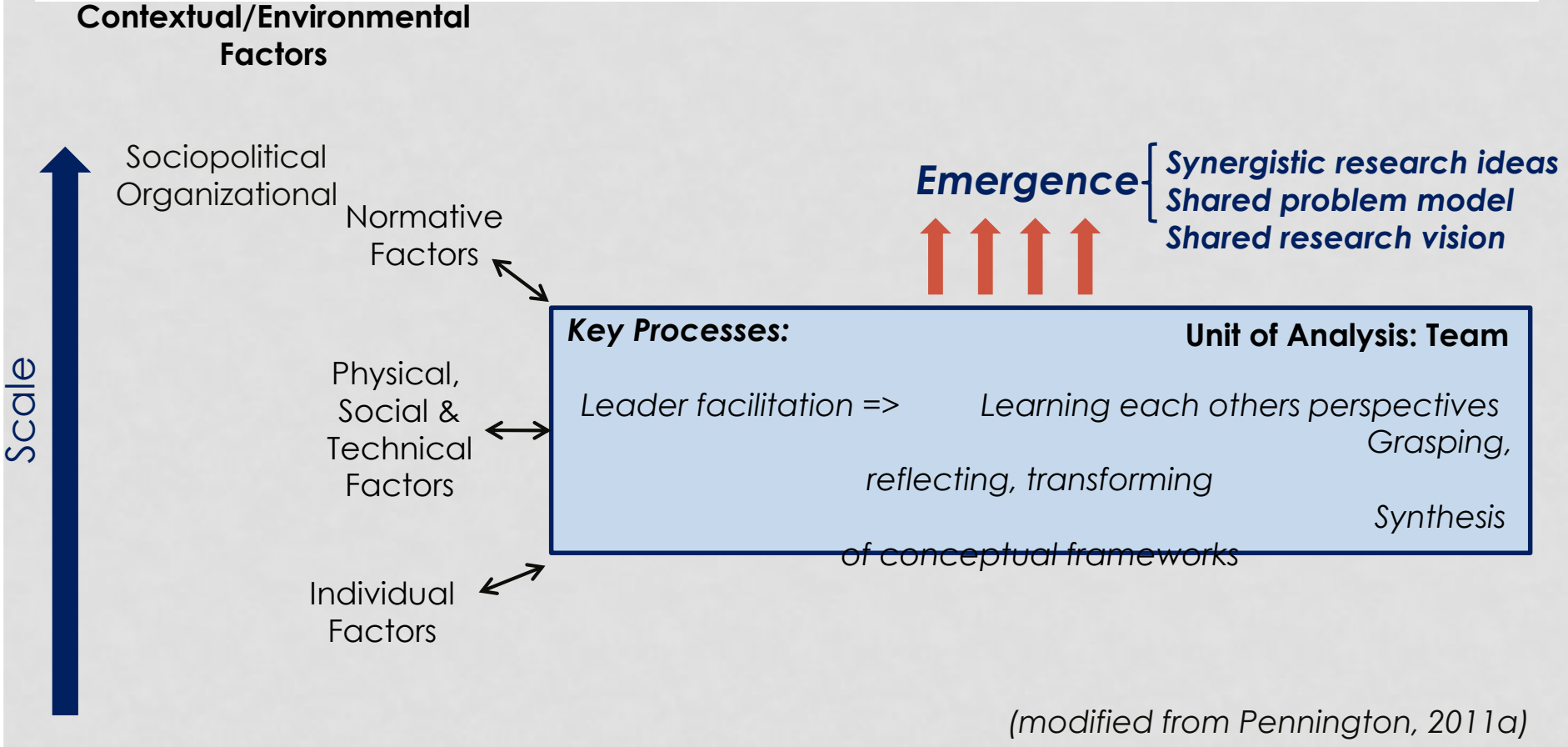
IT'S A LEARNING PROBLEM

- Mezirow (1975-): **transformational learning**: *disorienting experiences & reflection*
- Kolb (1974-): **experiential learning**: *iterative grasping and transforming*

Key processes:
- Iteration
- Grasping
- Reflection
- Transforming, connecting, synthesizing

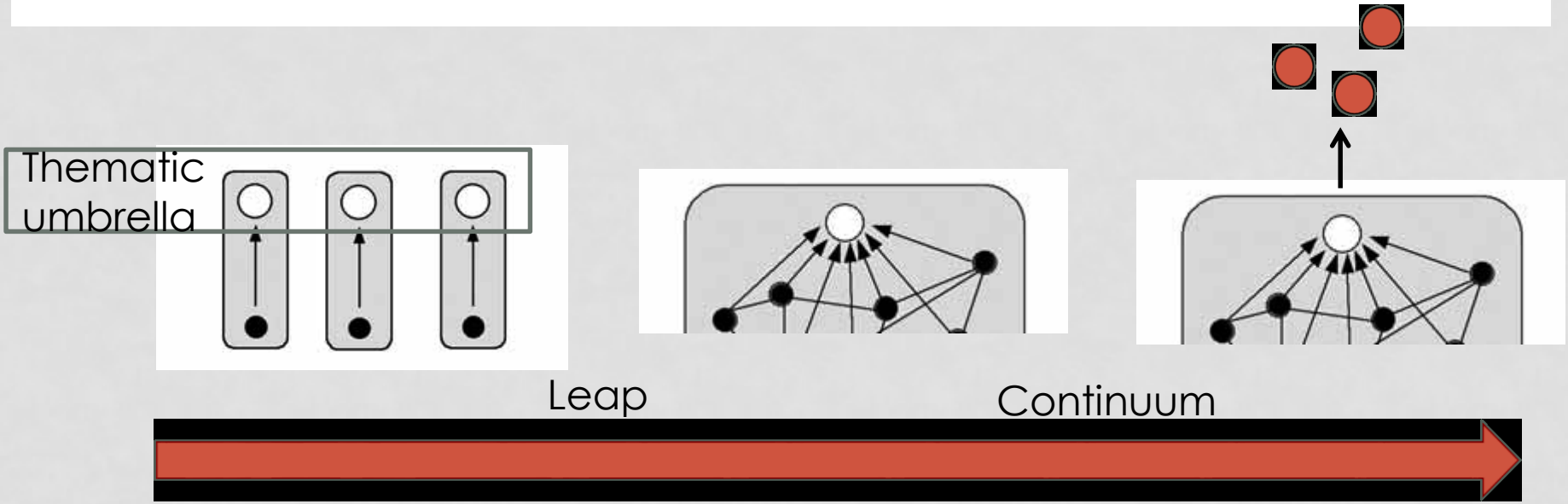
Pennington 2008, 2011a, 2011b, 2013)

LEARNING EMBEDDED IN DEVELOPMENT OF A COGNITIVE ECOSYSTEM



(modified from Pennington, 2011a)

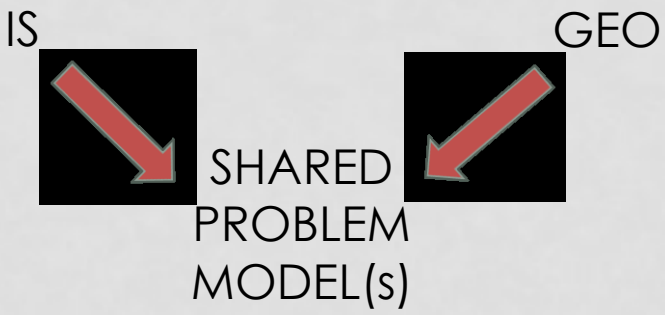
THE ROAD TO SUCCESS



Progressive learning*
Finding intersections*
Developing two-way research linkages
Developing conceptualizations
Developing frameworks

STRUCTURED MENTAL MODELING

Model-driven sensing
Knowledge maps
Theory-guided learning
Trusted threads
Interactive analytics



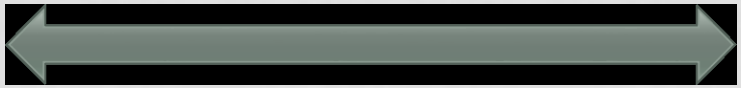
Atmosphere
Ocean
Polar
Geospace
Earth Science

Problem 1: IS research + GEO research
Problem 2: IS research + GEO research
Problem 3: IS research + GEO research

STRATEGY

No structure
Ad hoc dialogue
No progress

Firm structure
Research presentations
No understanding



How NOT to do this

WORLD CAFE

- Good example of light structuring, participatory process
- Attention to certain methods and behaviors can improve upon this

Employing Model-Based Reasoning in Socio-Environmental Synthesis

THE EMBERS APPROACH

Funded by NSF NRT-IGE (2015-2017)
Based on a decade of prior research synthesizing evidence from learning, organizational, social, and cognitive sciences

NSF grants:
#OCI-1135525 (2006-07)
#OCI-0753336 (2008-10)
#OCI-0636317 (2010-13
SESYNC award (2013-15) with NCSE
Pennington 2008, 2010, 2011a, 2011b, 2013, 2016
Pennington et al. 2016, Gosselin et al. 2016

EXTERNAL REPRESENTATIONS

- Star & Griesemer (1989) **Social sciences**: Boundary objects – static objects that link across different perspectives (forms, etc.)
- Hutchins (1995): **Anthropology**: Material artifacts in distributed cognitive systems
- Ewenstein & Whyte (2009) **Organizational sciences**: Epistemic objects – evolving objects
- Fiore et al. (2010) **Psychology**: Macrocognition – team process and external representations

MODEL-BASED REASONING

Models: Analogies, metaphor, thought experiments, visual models, semantic models and/or simulation models…
used for abstraction and communication of complex concepts

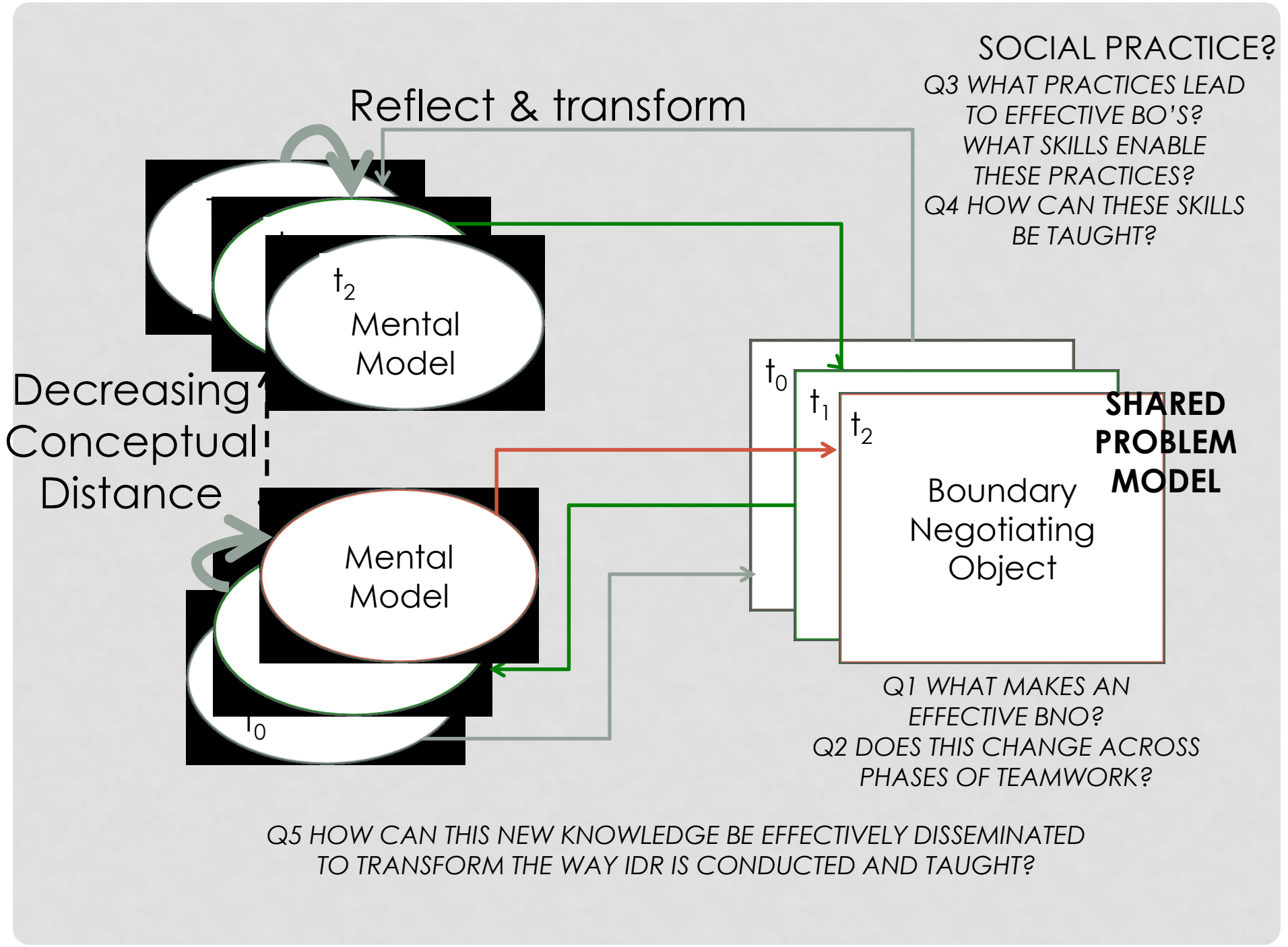
Models enable the offloading and summarizing of complex information so that individuals can *grasp* and manipulate more information

(Ifenthaler 2013)

Model-based reasoning:

- Employing models to *invoke conceptual change* [e.g. learn]
- Reasoning by mental modeling possibly aided by external devices

(Nersessian 1999)


SOCIAL PRACTICE?
Q3 WHAT PRACTICES LEAD TO EFFECTIVE BO'S? WHAT SKILLS ENABLE THESE PRACTICES?
Q4 HOW CAN THESE SKILLS BE TAUGHT?
Reflect & transform
t2
Mental Model
Decreasing Conceptual Distance
Mental Model
t0
t0
t1
t2
SHARED PROBLEM MODEL
Boundary Negotiating Object
Q1 WHAT MAKES AN EFFECTIVE BNO?
Q2 DOES THIS CHANGE ACROSS PHASES OF TEAMWORK?
Q5 HOW CAN THIS NEW KNOWLEDGE BE EFFECTIVELY DISSEMINATED TO TRANSFORM THE WAY IDR IS CONDUCTED AND TAUGHT?

THE EMBERS APPROACH TO STRUCTURED MENTAL MODELING

INCORPORATION OF EXTERNAL REPRESENTATION

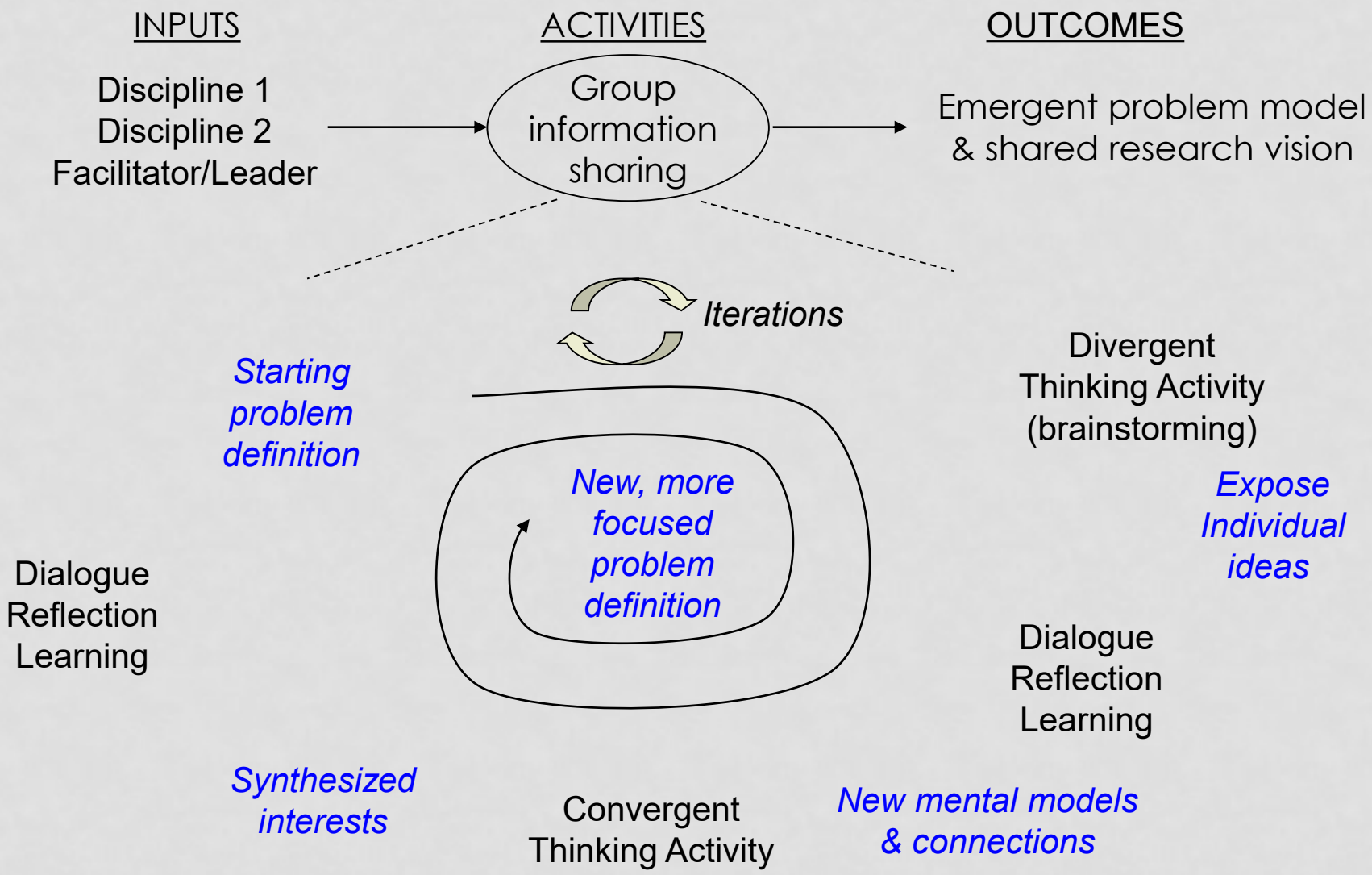
- Every activity includes drawing, diagraming, charting, etc.
- These are created and co-created by all group members
- Intentionally **invoke model-based reasoning**

PURPOSEFUL INDIVIDUAL REFLECTION

- Journaling: Every time you feel a spark of a good idea, **WRITE IT DOWN**
- Make time as part of the process to discuss these ideas

STRUCTURED PROCESS

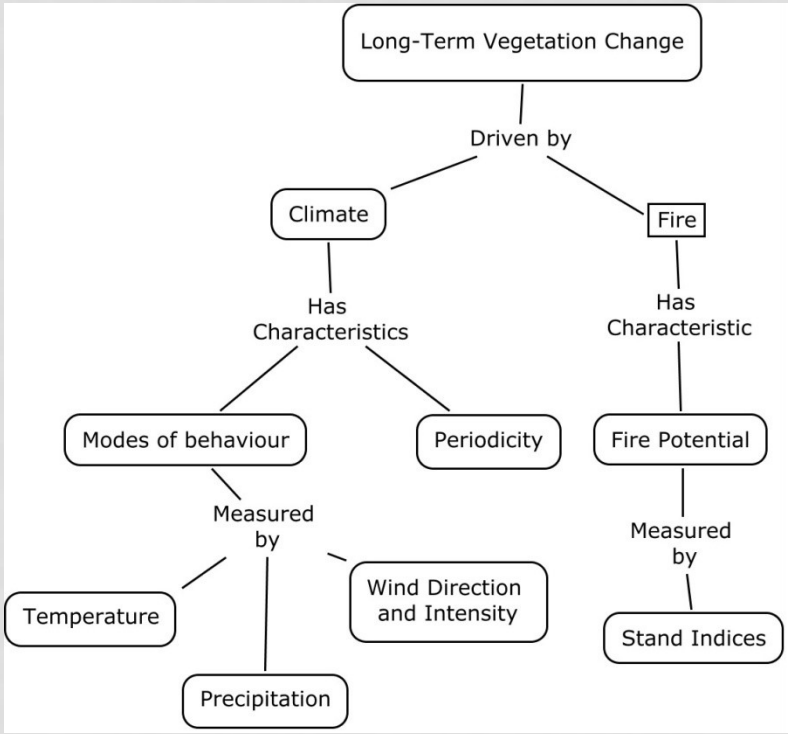
- Problem-based – work on real (scientific) problems
- Participatory – everyone has a turn
- Include co-created external representations (visuals, tables, graphs, etc.)
- Cycle individual reflection with group interaction
- Cycle divergent and convergent thinking
- Iterate, iterate, iterate



Modified from Pennington 2011

EXAMPLE: 2006 CS & ESCI

1. (Individual) Each person draw a concept map of their own research.



EXAMPLE: 2006 CS & ESCI

2. (Group divergent) Share each concept map with the group, one at a time. Focus on teaching and learning mental models and vocabulary. Purposefully take time on each to discuss possible linkages with the other discipline. Journal any emergent ideas.

EXAMPLE: 2006 CS & ESCI

3. (Group convergent) Compile a list of journal ideas. Comment on each other's entries. Group similar ideas. Identify synergistic problem areas. Create table of joint research areas.

EXAMPLE: 2006 CS & ESCI

4. (Individual convergent) Reflection on the identified areas. Concept map personal research interests to problem areas.

EXAMPLE: 2006 CS & ESCI

5. (Group divergent/convergent) For each identified area, create a focus group. Co-create an visual diagram that captures the integrated conceptual framework.

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SUGGESTION FOR 3:30 GEO SESSION

Create a chart that maps specific GEO problems to the IS research thrusts

	EXISTING SCIENCE EXAMPLE	POTENTIAL IS-GEO EXAMPLE FROM PARTICIPANT RESEARCH
Model-driven sensing		CT: Arctic winter erosion
Theory-guided learning		
Knowledge maps	GEON rock taxonomy	
Trusted threads		
Interactive workspace		DP: Data & model-based reasoning

ONE BIG CAVEAT!!!

Depends on people sharing their ideas freely

*****THIS IS INTELLECTUAL PROPERTY*****

If someone's intellectual contribution generates a good research idea for you, you need to recognize them in any scholarly publications as either an acknowledgement or, if possible, a co-author.

EXAMPLE AUTHORSHIP CRITERIA

- Substantial contributions to the conception and design, acquisition of data, analysis, or interpretation of data
- Sufficient participation in the work to take public responsibility
- Drafting the article or revising it critically for important intellectual content
- Final approval of the version to be published

MANAGE EXPECTATIONS

- It takes significant time for a shared problem model to emerge. Resist the urge to target something too quickly.
- It takes significant cognitive effort. Expect to be mentally exhausted.

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IMME'S FOLLOW UP

Questions/Discussion/Follow up