Knowledge Integration across Disciplines

Dr. Deana Pennington

Associate Dean, College of Science

Professor of Earth, Environmental and Resource Sciences

University of Texas at El Paso

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# Challenges of Interdisciplinary Research Teams

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

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

Socio-Environmental Research Teams

Different knowledge: Freshman/Sophomore Core Curriculum

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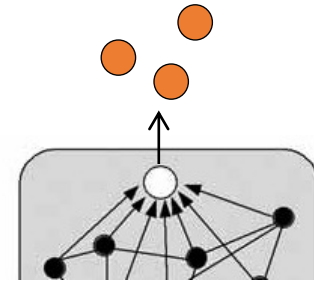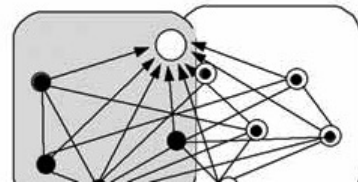Epistemologies
Uncertainty tolerance

Social Scientist

Natural Scientist

Computer & Information Science
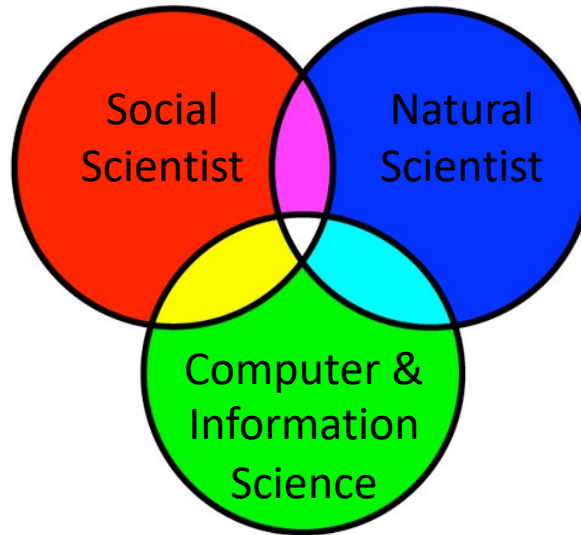
High cognitive distance between participants

Difficulties connecting knowledge

Vocabulary

- ● Researcher
- ○ Research goal
- ● Research frameworks

Disciplinary

Thematic umbrella

Multidisciplinary

Interdisciplinary
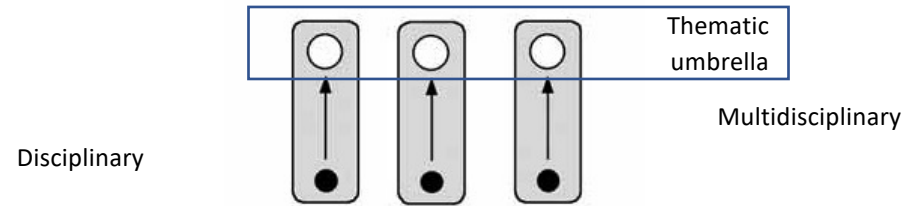
academic knowledge body

non-academic knowledge body

Transdisciplinary (1)

Transdisciplinary (2)

Modified from Tress, Tress & Fry 2003
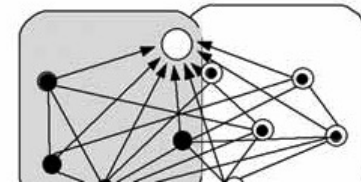
4

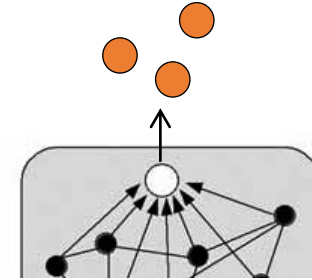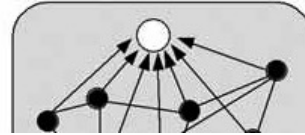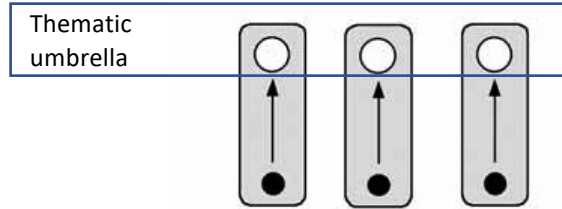# INTERDISCIPLINARY RESEARCH CONTINUUM

Developmental process of converging through time

Multidisciplinary   Interdisciplinary   Transdisciplinary

Thematic umbrella

Pennington et al. (2020)

2016

National Center for Socio-Environmental Synthesis (SESYNC)
Supported 58 teams through 2-3 year cycles
Program evaluation plus observation

"many teams do not allocate sufficient (or any) time during their first meeting to develop a shared (i.e., co-developed) concept of the research problem…Skipping this step not only limits the opportunity for innovation but can also potentially exclude the perspectives or input of individuals on the team. This can disenfranchise members and in the worst case reduce the research process to a disciplinary or multi-disciplinary mode."

Palmer et al. (2016)

Mental models

Defined: A person's internal, cognitive representation of an external reality, that allows them to interact with the world

- *Built on their personal experiences, knowledge, and perceptions of the world*

- *Incomplete representations of reality*

- *Inconsistent: dynamically adapt through time to changing circumstances and learning*

- *Form the basis of reasoning and decision making*

Jones et al. (2011)

Mental Models

Real world phenomenon
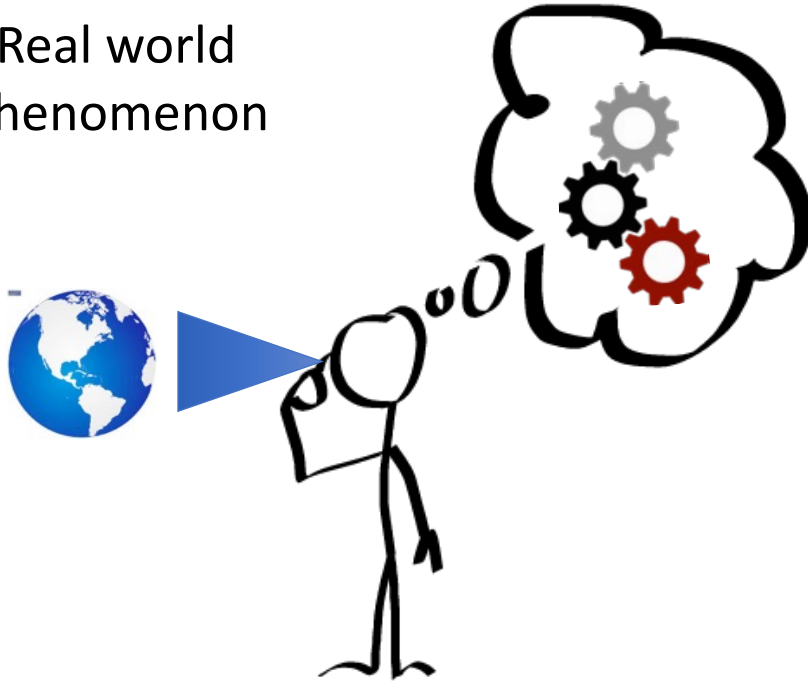
Our minds are rather messy places!

Explaining Perspectives

Explainer:
- Deep knowledge at research frontier
- Depends on many interrelated and foundational concepts
- Difficult to simplify & represent

Learner:
- Jargon unfamiliar
- No comparable mental model
- No perceived connections to their own knowledge
- Lack of intermediate concepts
- Misconception of concepts

Complex, ill-defined problems
A.K.A. Wicked problems

MENTAL MODELS OF THE PROBLEM

SHARED
VISION

LACKING
OR
VAGUE

UNCERTAINTY
AHEAD
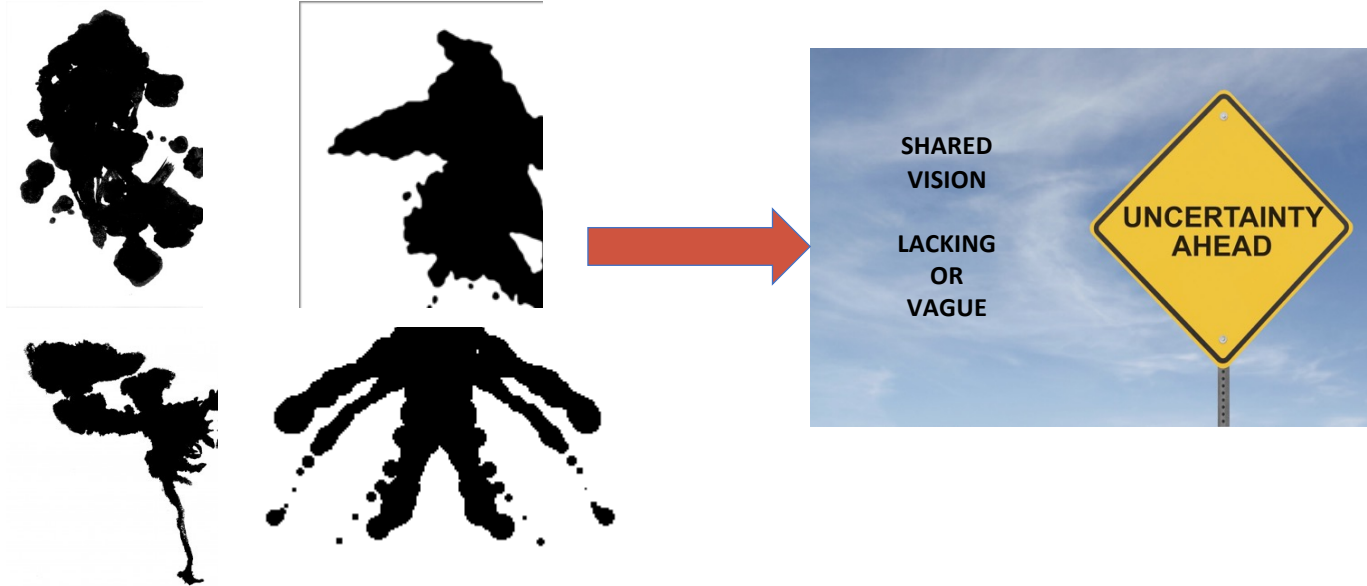
Disfunctional Teams:
"Failure to Thrive"

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

? ?
?

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

SHARED VISION
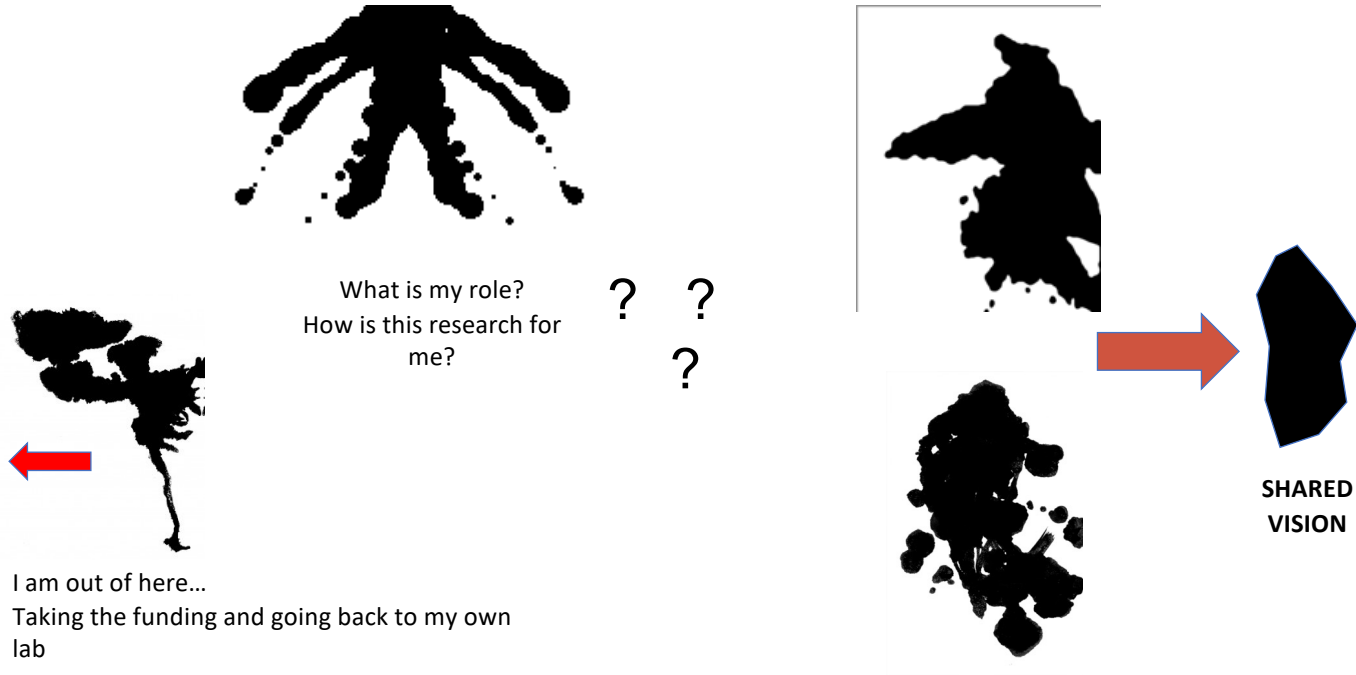
Power imbalance

Co-Create Shared, Integrated Mental Models of the Problem

Mental model

Shared problem model

Mental model

HOW???

Mental model

Mental model

Fiore (2004); Pennington et al. (2016)
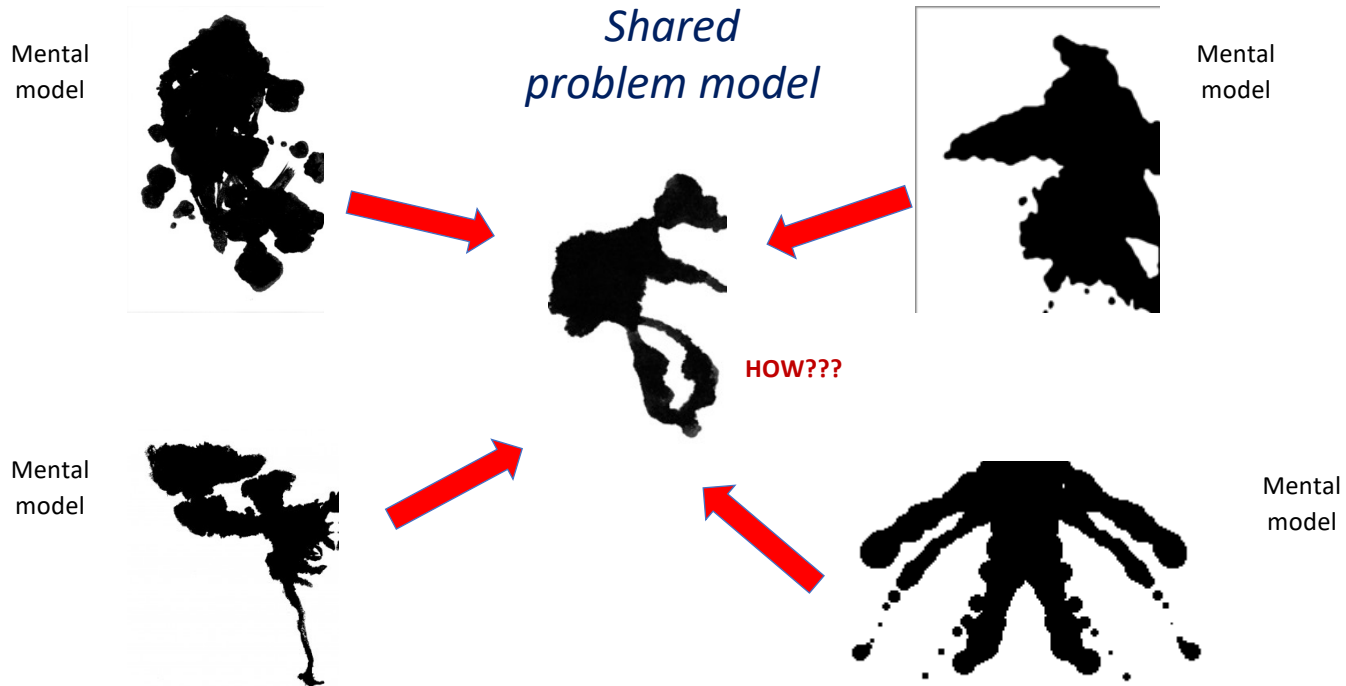
Interdisciplinary teamwork involves cognitive struggle!

- Deluge of new concepts and vocabulary that don't fit one's existing mental models
- New collaborators with different goals, values, and behaviors – different disciplinary cultures
- Unfamiliar data, methods, assumptions, epistemologies (what is a valid science)
- New tools

Godemann, 2008; O'Rourke et al., 2013; Pennington et al., 2013; Gosselin et al., 2020; Pennington et al., 2020)

Mezirow (1978-2014) studied disorienting life experiences that invoke transformative learning that substantially revises mental models to become **more comprehensive, more integrative**

Bransford et al. (2006) identified "conceptual collision" as the engine that **drives highly creative thinking** as new, orthogonal concepts are acquired and **mental models are subsequently transformed**.

It's a Learning Problem

Learning theories:

1. **Constructivism**
2. **Experiential learning**
3. **Transformative learning**
4. **Distributed cognitive systems**
5. **Model-based reasoning**

Model-Based Reasoning

Models: Simplification of reality
Analogies, metaphor, thought experiments, visual models, and/or simulation models…
*used for **abstraction and communication of complex concept**s*

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

(Ifenthaler 2013)

Model-based reasoning:
- Constructing models ***invokes conceptual change***
- **Reasoning by mental modeling aided by external devices**

(Nersessian 1999)

IDR teams: Co-creating visual representations develops
new linkages and concepts that connect across disciplines

"Convergence" on this!

- Star & Griesemer (1989) **Social sciences**: ***Boundary objects*** – static objects that link across different perspectives (forms, etc.) – 8k+ citations

- Hutchins (1995): **Anthropology**: *Material artifacts* in distributed cognitive systems – 12k+ citations

- Ewenstein & Whyte (2009) **Organizational sciences**: *Epistemic objects* –objects that unfold through time

- Fiore et al. (2010) **Psychology**: Macrocognition – team process and *external representations*

Our terminology

- **Boundaries**: Delineate a conceptual "space" within which one is working

- **Boundary negotiating**: Discourse intended to lead to a shared understanding of the boundaries of the problem (depends on the boundaries of the individuals at hand)

- **Boundary negotiating object**: Visual that facilitates negotiating the boundaries to be crossed, and how they can be crossed (Lee 2009)

Pennington et al. (2016)

Reflect & transform

PERSON 2

t_0

M

t_1

t_2

Mental Model

Decreasing Cognitive Distance

t_0

t_1

t_2

Boundary Negotiating Object

Mental Model

t_0

Pennington et al. (2016)

PERSON 1

SHARED MENTAL MODEL OF THE PROBLEM
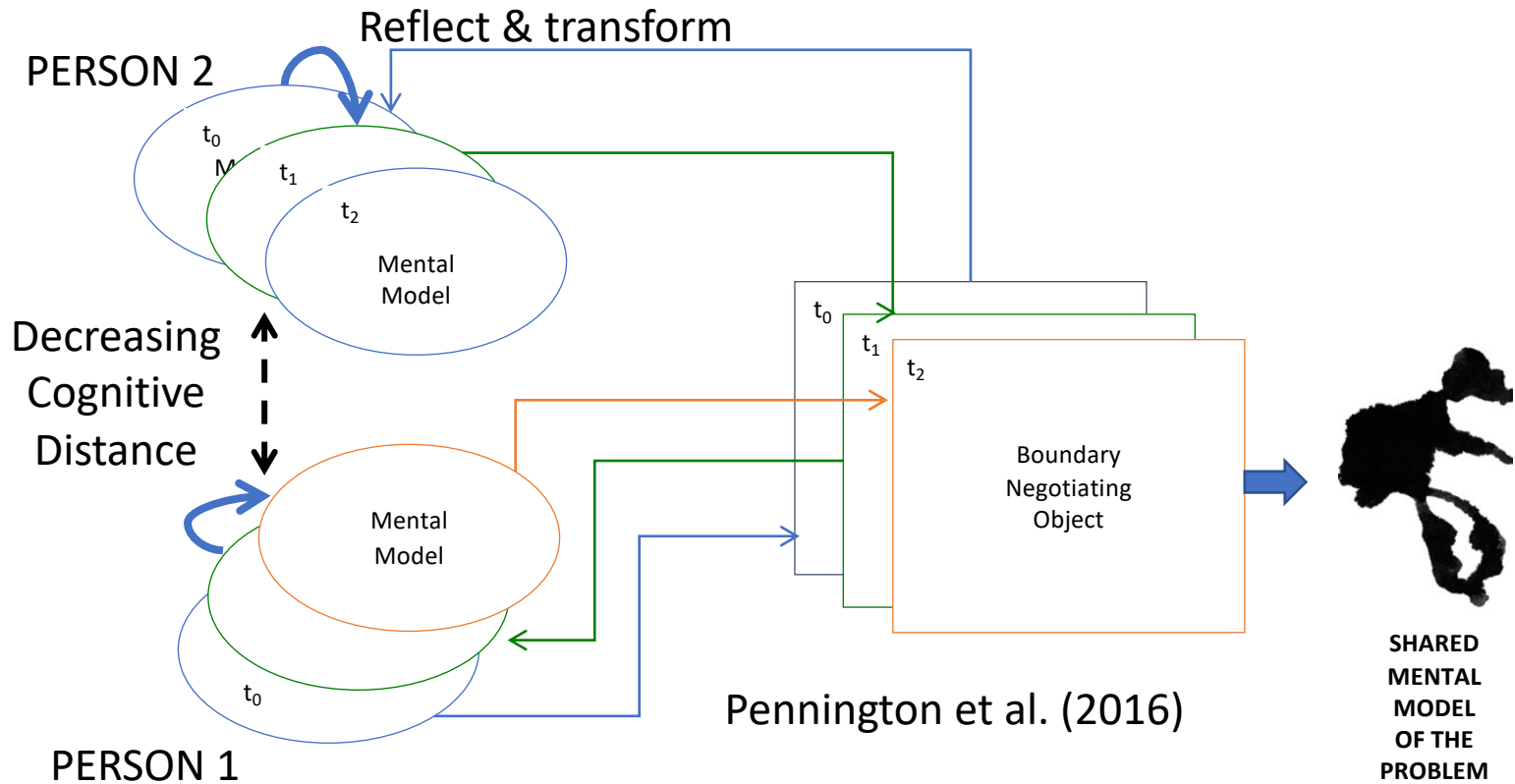
Employing Model-Based Reasoning in Socio-Environmental Synthesis

NSF #OCI-1135525 (2006-07)
NSF #OCI-0753336 (2008-10)
NSF #OCI-0636317 (2010-13
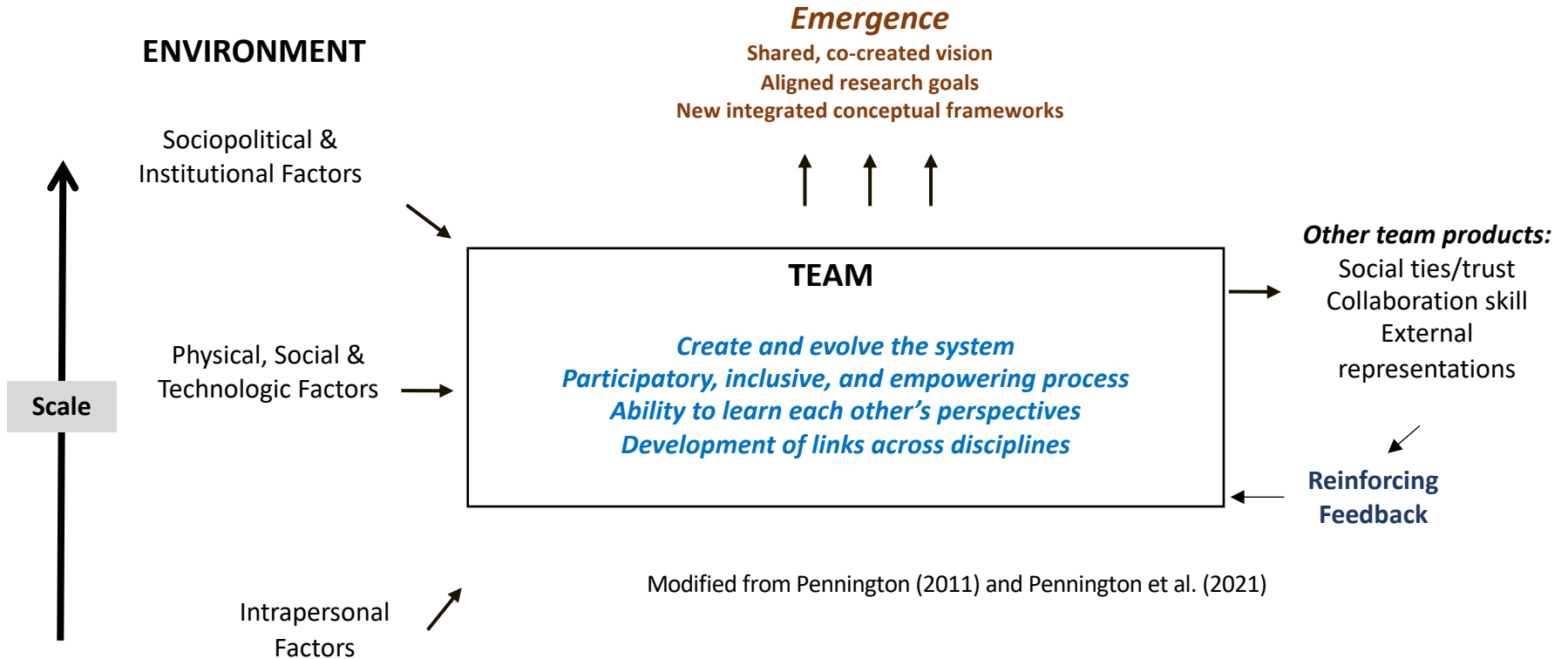SESYNC award (2013-15)
NSF NRT-IGE (2015-2019)

Q of I: How can we more effectively integrate knowledge (converge) across disciplines?

Lighting the fire of knowledge integration across disciplines

Interdisciplinary teams as socio-environmental systems!!

ENVIRONMENT

Emergence

Shared, co-created vision
Aligned research goals
New integrated conceptual frameworks

Sociopolitical & Institutional Factors

Scale

Physical, Social & Technologic Factors

TEAM

Create and evolve the system
Participatory, inclusive, and empowering process
Ability to learn each other's perspectives
Development of links across disciplines

Other team products:
Social ties/trust
Collaboration skill
External
representations

Reinforcing Feedback

Intrapersonal Factors

Modified from Pennington (2011) and Pennington et al. (2021)

Strategy

Ad hoc dialogue
No structure
No progress

How NOT to do this

⟷

Formal presentations
Firm structure
Little understanding

Borrego et al. (2014); Zajac et al. (2013)

- **General solution:** lightly structured participatory process focused on learning each others' perspectives
- **EMBeRS solution:** generate and co-create boundary negotiating objects that represent and progressively integrate mental models

In practice...every EMBeRS Activity is Comprised of 5 basic steps

- **1: Individuals organize their 'messy' thinking by creating a visual**

- **2: Turn-taking – individuals explain their thinking using the visual**

- **3: The team starts from scratch co-creating a visual**

- **4: Team reflection on the process and the outcomes**

- **5...n: The team iterates over this multiple times**

Sequenced activities => converge on integrated knowledge and shared vision

Today

- Identify problems to work on
- Set up teams
- Team zoom breakout rooms
- Team icebreaker
- Lunch break – Upload your research concept map to your team's Miro board. If you have not constructed your research concept map, you *must* do so and upload it before we resume at 1 pm
- Facilitated EMBeRS activity: Share and Link Your Research
- Group reflection: Overcoming Challenges of integrating knowledge

QUESTIONS??