Distributed Learning in Cyberinfrastructure Settings Comments at the DLAC Meeting Tubingen, Germany June 18, 2008

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Cyberinfrastructure/E-Science

- Existing computing data grids in the US and overseas
  - The TeraGrid project (http://www.teragrid.org/about/) combines the power of NCSA, SDSC, Argonne National Laboratory, CACR, PSC, ORNL, TACC, and various university partners integrated by the Grid Infrastructure Group at the University of Chicago. European e-science links facilities on the Continent with those in the UK. Similar activities occur in Japan. Industry partners include IBM, Intel, Hewlett-Packard and Oracle.
- The availability of massive data storage capacity and speed
  - The TeraGrid currently offers over 100 teraflops of computing power; and over 3 petabytes of rotating storage
- The development of middleware and software to gather and analyze stored data
  - The TeraGrid supports data analysis and visualization production interconnected at 10-30 gigabits/second.
- The emergence of large teams of scientists dedicated to solving shared science problems (acting through science "collaboratories" and "gateways")
  - A collaboratory (Wulf, 1989) is "more than an elaborate collection of information and communications technologies; it is a new networked organizational form that also includes social processes; collaboration techniques; formal and informal communication; and agreement on norms, principles, values, and rules" (Cogburn, 2003, p. 86). Collaboratories exist in many areas of science, including biology, chemistry, geoscience and astronomy (e.g., Chin & Lansing, 2004; Olson, Teasley, Bietz, & Cogburn, 2002).
  - Science gateways are web-based portals or interfaces for the structures and data of the cyberinfrastructure in many science areas (for a listing of 24 gateways, see http://www.teragrid.org/programs/sci_gateways/).
- Developments in scientific visualization. Scientific visualization draws on human spatial and visual processing in order to model and analyze computationally intense the graphic display of complex data (for a comprehensive review, see Thomas & Cook, 2005). Existing methods and models for scientific visualization are significantly challenged by cyberinfrastructure (e.g., http://www.teragrid.org/userinfo/data/vis/vis_gallery.php; Chin et al., 2006).
- Funding. The establishment and funding of national and international efforts to coordinate and develop the infrastructure to better serve science and, more recently, education (e.g., the Office of

Challenges for **Integration with Formal Education**: **Measurement** and **Methods**

- (1) to characterize **cyber-enabled learning using a case study**;
- (2) to identify **the assessment and psychometric issues** related to assessing cyber-enabled learning; and
- (3) to propose **methodological solutions** to modeling learning in such complex learning environments **– a topic for another time**!

Given the emergent, self-organizing and complex character of cyberinfrastructure:

- What is the character of analytical reasoning for geoscience within a networked, cyberinfrastructure framework, and
- What counts as evidence for such reasoning among scientists/students? What assessment and psychometric issues must be addressed?
- What are the methodological challenges in modeling and assessing learning within this cyberinfrastructure project? For example, how are **claims of causality** handled in a complex networked and nested learning environment, and what evidence would make such claims credible (e.g., Kelly & Yin, 2007)?
- Kelly and Sloane welcome insights and suggestions for dealing with the measurement and methodological questions that arise within distributed virtual organizations of scientists and students.

A Working Example from Geoscience

- Traditional radar, which uses radio waves as the means of detecting distances from the source, are of limited value in precise measurements due to the length of the radio waves.
- LiDAR (Light Detection and Ranging) technology allows the use of wavelengths in the ultraviolet, visible, or near infrared range (from about 10 micrometers to the UV (ca. 250 nm). These shorter wavelengths allow detection of smoke and other diffuse particulates, which has led to the use of LiDAR in meteorology.
- For earthquake prediction, LiDAR can be used to locate faults, and to measure uplift. Faults describe the line of fracture and demarcation between plates.
- For uplift, the significant advantage of LiDAR over radar is that LiDAR can generate digital elevation models (DEMs) of the shape the earth’s surface at resolutions not previously possible.

Earthquakes are Sometimes Associated with Volcanoes

- For example, the “Pacific Rim of Fire” is associated with colliding tectonic plates.
- In such cases, LiDAR may be used not only to make precise measurements of elevation, but also to characterize the density and even the chemical makeup of the gases and ash emitted by a volcano. LiDAR data on Mount St. Helen’s volcano may be found at http://wagda.lib.washington.edu/data/type/elevation/lidar/st_helens/

What does it Mean to Learn Networked Geoscience with LiDAR?

- Science of radar technology vs LiDAR technology,
- The science of plate tectonics (faults, uplift),
- Digital elevation models,
- Reading and understanding computer visualizations,
- Modeling complex inter-related scientific processes – real time and data-mined,
- Modeling distributed multi-expertise learning and cognition in a networked environment over time

For Students:

- Necessary prior scientific concepts?
- Necessary prior mathematical concepts?
- Necessary prior reasoning-with-evidence competencies?
- Networked learning competencies?

Some of the Cognitive-Measurement Challenges

- Which of these **concepts** (or other related concepts) are most pertinent **for scientists** in a cyberinfrastructure research collaboratory will be an empirical question.
- How to identify the **central constructs pertinent to a high-school** science education will provide a significant measurement challenge,
- **Identifying and mapping out multi-level content and cognitive demands** of such measurement will be a major issue.
- Since learners in cyber-enabled environments are also being actively challenged to think like scientists, we **need to measure changes in students**' **epistemological beliefs in science** by Stillings (Stillings, Ramirez, & Smith, 2004).
- Of particular interest will be **how to establish content, construct, predictive, concurrent and other forms of validity for these measures**, including
- **how to design (new) authentic model-eliciting problems** to measure understanding of these concepts.

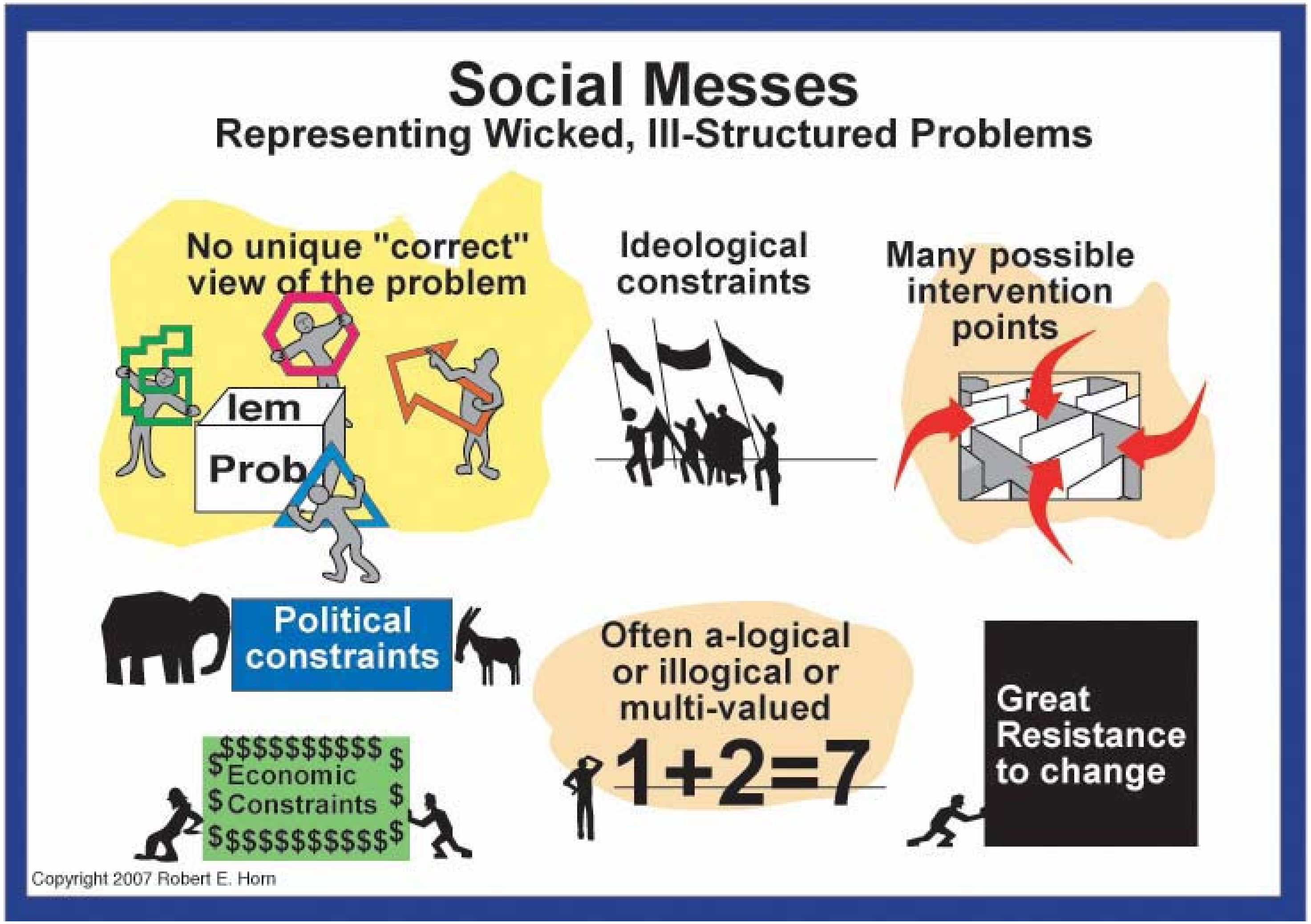
New Forms of Assessment?

- **Model-eliciting activities** have been used extensively for mathematical reasoning (e.g., Lesh et al., 2000), reasoning in engineering (e.g., Diefes-Dux et al., 2004; Moore, & Diefes-Dux, 2004) to address deeper knowledge of engineering concepts (e.g., National Academy of Engineering, 2005), and reasoning across distributed technology networks (e.g., Hamilton et al., 2007).
- **Developing and testing model-eliciting activities** for networked geoscience (primarily constructs describing earthquakes and tsunamis) may provide the **construct elaboration** necessary to build and test items of more standard form (Nitko & Brookhart, 2007).
- We need **design assessment**: (1) Understand the appropriateness of the evidence for the innovation;
- (2) Document the scientific evidence in support of the design of the intervention;
- (3) Embrace design and development; and
- (4) Measure a broad range of variables. Baker (2007, pp. 42-

Realizing the Target Terrain is “Wicked”, even for Scientists, Complexifies the Design-Based Research and Assessment Challenges

Recognizing the nature of the “wicked problem” (Rittel/Webber/Conklin/Horn & Weber)

- There is no definitive formulation of a wicked problem.
- Wicked problems have no stopping rule.
- Solutions to wicked problems are not true-or-false, but better or worse.
- There is no immediate and no ultimate test of a solution to a wicked problem.
- Every solution to a wicked problem is a "one-shot operation"; because there is no opportunity to learn by trial-and-error, every attempt counts significantly.
- Wicked problems do not have an enumerable (or an exhaustively describable) set of potential solutions, nor is there a well-described set of permissible operations that may be incorporated into the plan.
- Every wicked problem is essentially unique.
- Every wicked problem can be considered to be a symptom of another problem.
- The existence of a discrepancy representing a wicked problem can be explained in numerous ways. The choice of explanation determines the nature of the problem's resolution.
- The planner has no right to be wrong (planners are liable for the consequences of the actions they generate).
- Kelly, Lesh & Baek (2008). Handbook of Design Research Methods; Kelly (2003), special issue of JLS, (Barab)



http://www.strategykinetics.com//New_Tools_For_Resolving_Wicked_Problems.pdf

Horn, Robert E., and Robert P. Weber; *[New Tools For Resolving Wicked](http://www.strategykinetics.com//New_Tools_For_Resolving_Wicked_Problems.pdf)*

What is Instructionally Available?

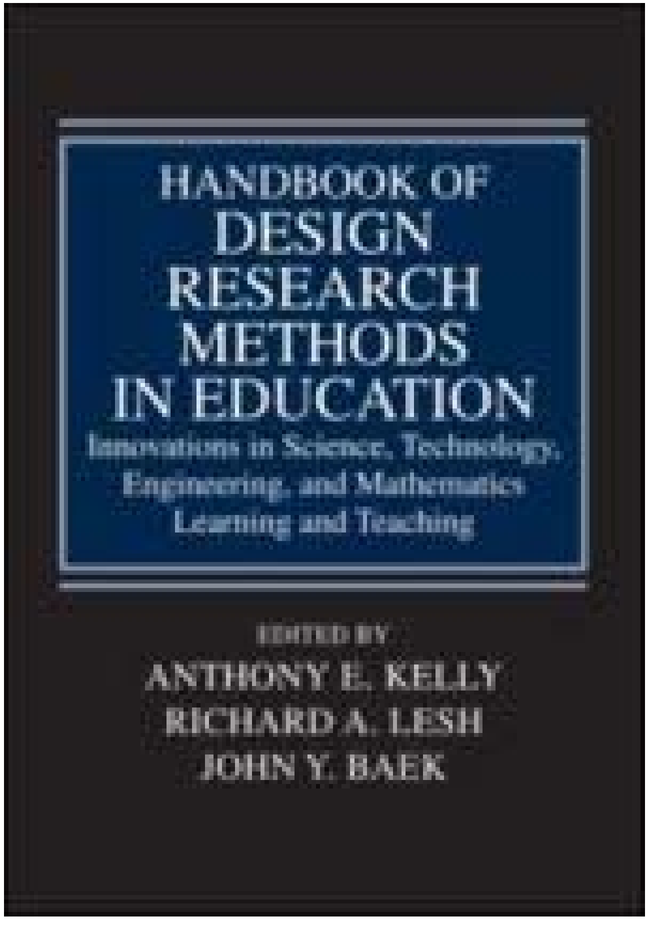
- Learning about geomorphology using LiDAR is complex, and some publicly available web sites have attempted to provide instruction (e.g., http://lidar.cr.usgs.gov/ and http://gisdata.usgs.net/website/lidar/viewer.php).
- The most comprehensive activity has been conducted by the GEON network (http://www.geongrid.org/). This network is part of the cyberinfrastructure research collaboratory, which will be a partner in the proposed work of this grant.
- Tutorials on the use of LiDAR within and outside of geoscience (e.g., coastal erosion, flooding, river courses, forest mapping and mining) may be found here; http://home.iitk.ac.in/~blohani/LiDAR_Tutorial/Airborne_AltimetricLidar_Tutorial.htm.

Design Methods for Networked Learning . . .

- Learning experiments in 3-space: time; learning/cognitive processes; performance
- Theories of cognition have been arrived at after considerable experimentation at very small scale (studies of cognition in the content area and small studies of distributed learning on a small scale);
- It is likely that the optimum conditions of learning on a small (lab type experimental) scale will usually provide no more than a good first approximation at a full scale (in this case a broad distributed system for learning);
- As such, it is likely that considerable modification of the conditions for learning arrived at from the small scale work will be necessary before a comparable result can be obtained in the distributed setting
- See chapters by Sloane in Kelly, Lesh & Baek (2008)

Design Research and the Study of Change: Conceptualizing Individual Growth in Designed Settings Finbarr C. Sloane and Anthony E. Kelly **Longitudinal Analysis and Interrupted Time Series Designs**: Opportunities for the Practice of Design Research Finbarr C. Sloane, Brandon Helding, and Anthony E. Kelly **Multilevel Models in Design Research**: A Case from Mathematics Education Finbarr C. Sloane

Modeling Complexity in Mathematics Education Donald Saari



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