Metacognitive Scaffolding in ICT-based Science Learning Working Group

Present:

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Paul Horwitz, Concord Consortium, Technology-Enhanced Learning in Science CLT

Raj Choudhury: Norfolk State University, Technology-Enhanced Learning in Science CLT

Mike Haney: NSF Program Officer for CLT Program

Discussion:

Bruce Herbert opened with a discussion based in part on his paper (with Leutner, Ehmke, Hofer, Prechtl and Renkl) entitled, *The Role of Metacognitive Scaffolding in Developing Mental Models*

Ecosystems change. Example from the historical record (16^{th} Century painting of abundant wildlife)

Ecosystems are extremely complex

Environmental science brings up social, value-laden issues.

It is interdisciplinary

Its problems are situated in a systems framework, often involve a time lag, and include nonlinear feedback, deterministic and stochastic processes, and irreversibility.

Data sets often include remote sensing data: e.g., concentration of surface PCBs in Lake Michigan from daily satellite data

Development of scientific models as depicted in education is generally linear and reductionist. This is too limiting a view. Example: conceptual, systems-based model of gene expression (taken from Science)

Second example: organizational Chart of the A&M CLT

Model-based course at A&M in which very participating student does a model-based learning-by-inquiry project. Example: Winogradsky columns model state of pollutants in estuarine sediments.

Projects couple small-scale models to large-scale (GIS) data

Texas has one of the least developed coastlines in the U.S. but it also has a very well-developed industrial environment. Plumes of pollutants focus on Galveston and Corpus Christi bays.

Future collaboration with Germany will involve exchange of junior researchers

A&M is going to introduce inquiry into their introductory geology course. The students will be more representative of what you might find HS classes – particularly in the gymnasium in Germany. They will put their materials in a weekly lab setting.

They want to build simulations that will allow them to test educational hypotheses. Content is open. Comment: university teaching is often behind HS teaching, at least in the U.S.

In Germany, university students who take science are necessarily science majors – there are no “liberal arts” science courses.

Manfred Euler: We have two dissertation projects involving modeling complex systems. Both use models and real data.

One of them is aimed at developing simple conceptual models linking climate change with global circulation. Central problem: how to understand sudden jumps in data in the context of the circulation model of the ocean. Temperature and salinity are variables. Stream of water driven by these two variables. Continuous – evolves to steady state. Add freshwater (e.g., through precipitation) and you may interrupt the whole process. Continuous variation in the new variable can lead to discontinuous behavior of the model. Hysteresis effects are also present. This might be a useful example to see how students deal with complexity.

The other one: simple mechanical system: a pendulum with a graphics tablet for capturing data. Couple multiple metronomes together.

Bruce Herbert: Major cognitive problems: systems that involve multiple variables, induction vs. deduction (confounding past behavior and prediction of future behavior), presence of multiple feedback mechanisms.

Detlev: possible collaboration between Herbert and Euler: choose a topic and do a single 4-hour lab.

In Germany, the HS curriculum is bifurcated and students are routed toward or away from science at age 13, with further specialization at age 16. So a comparison between a German gymnasium course and a U.S. entry-level college course might be in order.

Timo Ehmke: I see a good connection between Herbert and the Co-Lab project. Compare data from model to real data, for inclusion in HS courses. Herbert: we could build a learning system focusing on an environmental problem in U.S. and a similar problem in Germany. Would include a physical model, a simple computer model, and visualization tools applied to large, real datasets. Might use Co-Lab to get the German students to work with the U.S. students. Could use chat rooms or threaded discussion groups.

The purpose of the collaboration is to do research on scaffolding. Norfolk State could be a pilot site as well.

Horwitz: Brief description of goals of TELS and the Educational Accelerator.

Mike Haney: Accelerator technology may not be ready for Phase 1, but might be great for Phase 2. TELS is funded to provide the technology base for educational research.

Horwitz: longer description of Ed Accelerator. Seems to evoke lots of interest – especially with respect to the infrastructure for data collection.

Barbara Olds: Think about how NSF and DFG can help make this (embedding the INP/Texas models into the TELS infrastructure) happen in the short term. Should we send people back and forth?

Horwitz: Brief description of technical requirements.

Timo: Co-Lab is written in Java.

Bruce: Texas TAs would be selected from the graduate students who have gone through the Texas CLT program.

Detlev: What’s the next step? What do we report? We have people who are willing to think about constructing a complete science lesson based on inquiry, discovering, modeling. We will look at the effects of scaffolding. We will include the three components: physical model, computer model, real-world data set.

Horwitz: probeware can be important, too.

Hofer: Describes a self-monitoring tool. Quite elaborate “to do” aide for students to help them with planning and monitoring their own learning. Makes explicit their prior knowledge, learning goals, and plan. Then they do the learning, and then there is a post-learning recap and summary: what did you plan, what did you do, what’s the overlap between the two? Graphical report. Big problem: getting students to use the tool. It’s intended for university students, not high school.

Example: business students learning cost accounting. The experimental group had the tool and the control group did not. Two groups tested on knowledge acquisition. No difference on metacognitive strategy use, the group that used the tool had significantly greater learning gains, compared to the control group. Small n in that intervention, but the tool is now being used in another course (in psychology). Conclusion: it takes time to use this tool but it is effective.

Horwitz: Barbara White and John Frederiksen have done work on using software agents for helping kids create and use mental models. Someone else: Rosina Morino (Albuquerque) has done work on software agents for monitoring and scaffolding students’ learning process.

Horwitz: Suggesting: a possible mini-project might teach about the effect of negative feedback in very different contexts – e.g., mechanical oscillators and environmental systems.

Detlev: Should this be a bottom-up or a top-down approach? In other words, should we start with a problem that kids know something about (e.g., from the newspapers) and then give them a simple physical model to give them an insight, followed by introducing a dataset.

Bruce: Example: link between land use and aquatic ecosystems. Algal blooms. Non-linear dynamic system, Forced oscillation (driven by fertilizer use). Predator-prey model for response. The problem is that this is a very complex model to try to teach in 4 hours.

It may take 6 months to get funds from DFG.

We could deal with nature of science in 4 hours. Students think that science is constrained to be what is portrayed in the science textbooks.

Detlev: the task for the network is to prepare a proposal for a research project on computer-based, scaffolded, collaborative, inquiry-based science learning. Exploring ways to scaffolding hypothesis generation and testing in such a discovery environment. How to use visualizations. Expertise in cognitive load and multimedia. Planning to start soon, full proposal to appear in one year (for a five-year project).

Choudhury wants to bridge between this group and the TELS project. Interested in non-science learners.

Manfred Hofer: interest in motivating non-motivated students.

Manfred Euler: interest in how students understand complexity and in inquiry learning.

Timo: interest in simulations for learning, collaboration.

Joachim: interest in psychogical processes, datamining.

Horwitz: interest in exploring ways in which the TELS technology base might be useful to this enterprise.

Talk by Barbara Olds: where is the REC Division headed?

We brought in experts and asked them:

1. What are the trends in STEM education and where do you think the field is headed?
2. In what areas is the most creative work being done?
3. What are 3 or 4 questions of national importance where there has been little progress and 3 or 4 where we have a reasonable accumulation of knowledge?
4. Major obstacles or threats to progress in STEM education?

They came up with the “seven Cs”

Capacity Building:

Shortage of people going into ed research

Lack of diversity

Not enough mechanisms to attract grad students and postdocs into ed

Ed researchers need knowledge of content and methodology

Tools expensive and difficult to develop

Disagreements about assessment purposes and instruments

Cumulativity

Insufficient mechanisms for building ed research and evaluation cumulatively

Value of individuality and originality results in isolated knowledge “silos”

Field is disputatious

Data sharing not widely practiced for both value and practical reasons

Time from research to application much too long

Collaboration

Too few interdisciplinary approaches

Need for vertical collaboration (K-12 and higher ed) and international collaboration

Potential models (e.g., communities of practice) exist

Stakeholders seldom have input into evaluation or research studies

NSF can itself provide a model of collaboration

Context

Not “what works?” but “what works for whom and where?”

Audience analysis and context are important

Evaluators also need to be sensitive to context

Conditional Studies

Methods must be appropriate for the maturity of research

Knowledge base is insufficient in many areas of STEM to justify doing large scale randomized clinical trials

EHR should fund more “conditional” or “beta” Phase 1 and 2 studies that build on exploratory “phase 0” research before going to large scale studies.

Communication

Distinction between informational and transformational communication

“Knowledge chums” can bring about greater consensus based on research, evaluation, practice, and ordinary knowledge

Need for communicating findings

Research on communication is largely absent from NSF portfolio

Cyberinfrastructure

Both a tool for conducting research and an object for study

Many technologies have not been adequately researched to determine their impact..

Implications for DFG/NSF Collaboration

Need to explore ways to:

Increase capacity

Build on existing knowledge

Link research and practice

Use technology effectively

Talk by Judith Ramaley: Where is EHR and where is it going?

NSF has education mission described in a "powers of three" writing style:

- "discovery, learning and innovation" achieved through
- "development of intellectual capital, integration of research and education, and promotion of partnerships" in order to
- "make it possible for US to uphold a position of world leadership in science and engineering,
- "promote the discovery, integration, and dissemination of research results,"
- "promote excellence in education."

Criteria for evaluation:

- "Intellectual merit of the proposed activity"
- "Broader impacts of the proposed activity"

The second one is new and somewhat surprising.

NSF in general

The only agency that conducts non-mission oriented research.

Spends about 4% of the total federal research outlay.

"The little agency that could."

Workforce for the 21st Century Priority Area

Prepare scientists and educators to meet the challenges of the 21st century

Attract more US citizens to STEM fields

Broaden participation in STEM fields

The EHR Directorate: Meeting the needs of a changing student population

The people entering the workforce need to know more than the people leaving it.

Supply of highly skilled people is limited unless we solve inequities

Many of our young people are ill-prepared to meet the challenges. There is a huge gap between the best prepared and the least prepared.

The pathways to a credential are growing more complex

Core themes in the EHR portfolio

Changing nature of science.

Problems transcend traditional disciplines: implications for the organization of universities

Examples: complexity theory. A new paradigm?

Blood vessels are not pipes

Impact of technology

Changing pathways to careers

Building a knowledge base

Evaluation as a shared element

Core investment areas

Building capacity

Research in the science of learning

Translating research into practice

Creating supportive learning environments

Ensuring that the STEM community is broadly representative

A culture of evidence in EHR: Infusing a research mindset

Cycle of Discovery, Innovation and Application

Communication does not simply mean publication

How do you provide validation in the research community and also infuse the other relevant communities of policy setting and educational practice?

Will the EHR work ever make a difference in anyone's life?

EHR initiatives

Nanotechnology

Adding to increased understanding of cognition itself.

Math curriculum problem (in response to a question from Horwitz)

Conflict in the mathematics community – disagreement as to what real math is attainable by pre-college students. NSF is going to work on "gifted and talented" program. "I am fond of the NRC's efforts to define what math ought to be taught. We are reviewing our math curriculum and trying to find out what we have been supporting. 1200 projects. I don't know if we'll end up with a coherent position. Mathematical competency is different from what research mathematicians do."

Bill Frascella (ESIE Division Director): The research workforce is different in math. There is movement in the areas of simulation, modeling, big data sets. The model of the virtuoso practitioner still has a major foothold in math. The heroic ideal of doing everything with a piece of paper and a pencil still lives on and makes the acceptance of change more difficult in math than it is in science.

Back to the metacognitive scaffolding working group…

Goal: proposal by next September.

Timeline:

Meeting (end of April) with Bruce, Raj, Manfred E., at IPN to figure out the subject matter of the 3-to-4 hour lesson. Learning goals must be defined. Outcome: a paper with an outline of the simulation and the lesson.

Next step: meeting (in May, June?) of the psychologists at IPN to figure out the scaffolding required. Concept paper to be written around the end of June.

Joint meeting (one week in September) in Texas to write the proposal.

Lesson to be taught in the Spring of 2005 in Germany, Texas A&M and Norfolk State.

Scale of the project: 2 years (+ 1 year?). Must involve young researchers. Second year might involve a second module. The project will evaluate the effectiveness of the international collaboration as well as whether anyone learns anything. Possibility for pilot studies as well as regular classroom implementations followed by controlled experiment. Rapid design cycle.

Question: can we get the travel money before the concept paper and proposal are written?

First year: joint project. Second year would participants to deviate a bit in response to their needs and interests.

The German group will send around emails to everyone telling us what they need in the way of support writing.