Representation and Communication Infrastructures

Matters regarding Simulations as Executable Representations, Forms of Expression, Activity Structures and Classroom Participation

Trilogy Lecture 3
Professor Stephen Hegedus
Friday February 8th, 3.30-5pm
Kaput Center
Traditionally Educational Technology is

**Tool**
- e.g. Graphing calculator, CAS

**Cognitive Tutors**
- Interactive progressive support

**Media**
TECHNOLOGICAL BANALITIES

All are external

Not personal as a media but can be enhanced

Are artefacts or tools
... environments which can guide the user and be guided by the user - theory of co-action (Moreno & Hegedus)
But common to all .....
SimCalc MathWorlds(R) is used by over 15,000 students in 12 countries.

Integrates dynamic visualization with wireless connectivity to transform communication in the classroom.
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UMass Donahue Institute
It's family first for Colts' tiny terror

Giuliani: Can hero of 9/11 win over his own party?

Damage of Exxon Valdez endures

Far-ranging' toll from '89 oil spill
More counterfeit cash in circulation

For the last five years, the amount of counterfeit U.S. currency that passed into circulation before being caught exceeded the amount that was seized before hitting the marketplace. Total U.S. counterfeit currency activity:

(in millions)

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Source: U.S. Secret Service

By Karl Gelles, USA TODAY
What is a Graph?

Maps, astronomical drawings: very old

Modern forms: appeared in 1770, became common 1820
Appeared in 3 places: Statistical atlases of William Playfair, Indicator diagrams of James Watt, writings of Johann Lambert (also descriptive geometry of Monge)

Sylvester used it to describe analogies between chemical bonds in molecules and representations of mathematical invariants and covariants

Peirce wrote: "by a graph (a word overworked of late years), I, for my part, following my friends Clifford and Sylvester, the introducers of the term, understand in general a diagram composed principally of spots and of lines connecting certain of the spots." Peirce called his logical diagrams “existential graphs” because of the spots and lines

Graph has taken on an extended meaning in 20th century
SIMCALC MATHWORLDS
SimCalc Demo of V-Graphs
What is a graphical representation - semiotics talks about “points”, digital semiotics talks about executable reference to see through the graphical sign.

Dynamic mathematics can “see through” graphical signs.

Graphical interpretation (symbolizing) is understanding change and motion.
SimCalc Demo of Communication
Highly Adaptive, Interactive Instruction

Software affordances

Participatory-infused curriculum

Adaptive, intimate pedagogy
COMMUNICATION INFRASTRUCTURE

Facilitate work-flow,

Aggregate student constructions to: i. vary essential parameters on a per-student basis, ii. elevate student attention from single objects to parameterized families of objects,

Provide opportunity for generalization and expose common thought-patterns (e.g. errors)

Students create change and variation

Activity structure
Changes in modes of expression
Gesture, Talk, Action ...
New levels of engagement

Studies in MA showed that SimCalc can impact motivation as well as learning through participation INSIDE the classroom.
Student Identity

Students experience and contributions are embedded in a social workspace.

Mathematical structure and understanding can be emergent, e.g. What do you expect to see before I show you the ... {graphs}

Representational infrastructure includes data management systems to manage the flow of information and examination of mathematical substructures; such power serves a variety of pedagogical needs, and
PEDAGOGY

Students make personally meaningful mathematical objects to be publicly shared and discussed.

Students project their personal identity into the objects and constructed motions.

Students mathematics and social experience are deeply intertwined.

Teacher are in a central role to orchestrate whole class of events.
TECHNOLOGY TRANSFORMING IDENTITIES

Technology as representational, communication infrastructures co-exist inside classrooms.

Re-think curriculum at deep epistemological levels and understand from history how epistemological ruptures transformed our understanding of the universe and the advancement of science.

Technology as infrastructural is breaking down the epistemological barriers and becoming more transparent percolating Dynamics of social & meaningful participation back to the surface.

Technology as Co-action: we guide and are guided by the reactions of the environment.
Motivation to learn is not just about self-efficacy or self-value but identification of the self vis-a-vis others:

How do we participate and represent our thinking?

How are we represented by and perceived of by others?

Students are not motivated to learn because they are not participating in meaningful ways; does not intersect with the content they are learning

Modifying participation structures through new technologies can alter student identities, enhance creative practices and impact learning
Instruments

Mathematics Algebra 1 Content Test 1 & 2

Student Attitude Survey

Teacher Background Survey

Teacher Attitude Survey

SimCalc Teacher Daily Logs

Logs measuring implementation (for measuring fidelity)
Student Attitude Survey

Four Constructs:

1. Positivity towards math and school (α=.717)
   • “I think mathematics is important in life.”

2. Working collaboratively & related affect (α = .692)
   • “I sometimes feel nervous talking out-loud in front of my classmates.”

3. Working privately (α = .727)
   • “I learn more about mathematics working on my own.”

4. Technology (α = .674)
   • “Technology can make mathematics easier to understand.”
No significant correlations for the comparison group
CASE STUDIES

Classroom from each group
demonstrating high pre-post test student gains

Veteran teacher and well-experienced teacher (5 yrs) - both used SimCalc but the comparison is not in this study.
No significant correlations for the comparison group
Ratio of Student-Student Turns to Total Student Turns in the Class

\[ y = 0.0137x + 0.3593 \]
\[ R^2 = 0.52859 \]

- Class 13 (outliers removed)
- Class 5
- Linear(Class 13 (outliers removed))
- Linear(Class 5)

\[ y = 0.0027x + 0.0368 \]
\[ R^2 = 0.12734 \]
Cluster Randomized Study

**Algebra 1 Pilot Study 1 (Year 1)**
6 districts - total sample: 48 classes
N(classrooms) = 14 (7 Treatment & 7 Control)
n(students) = 254 (136 Treatment & 130 Control)
SimCalc replacement curriculum for 8-12 weeks

**Algebra 2 Pilot Study 3 (Year 2)**
3 districts
N(classrooms) = 7 (4 Treatment & 3 Control)
n(students) = 149 (78 Treatment & 71 Control)
SimCalc replacement curriculum for 6-8 weeks

**Algebra 1 Main Study 2 (Year 2) & Algebra 2 Main Study 4 & 5 (Years 3 & 4)**
7 districts - total sample: 60 classes
N(classrooms) = 28 (14 Treatment and 14 Control)
n(students) ≈ 700 (350 Treatment; 350 Control)
Algebra 1 SimCalc replacement curriculum for 8-12 weeks
Algebra 2 SimCalc replacement curriculum for 6-8 weeks
% Test Change (average)

Experimental Group

Error Bars: 95% CI
Gains by each class

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<tr>
<td>3</td>
<td>T</td>
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<tr>
<td>2</td>
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Group:
- C
- T
% Test Change (average)

Control

SimCalc

- Female
- Male

20.00
15.00
10.00
5.00
0.00

Male

34
% Test Change (average)

Class Level
- non-Honors
- Honors

Control
SimCalc

0.00
5.00
10.00
15.00

35
Error Bars: 95% CI
WeHS
WaHS
ORR
NBHS
GNBV
DHS
School

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WHAT DO TEACHERS DO?

focus on reasoning across multiple representations

Perform procedures/solve routine problems
Future Design Principles

Executable Representations
Mathematical objects and configurations should allow learners to dynamically manipulate and execute operations on the representations in the learning environment. Instead of dealing with static objects or computational outputs, representations that are flexible allow young learners to adapt the configuration and test out their conjectures in an iterative manner.

Co-action
The learner and learning environment should be collaborative. In dealing with flexible and executable representations, the actions of the learner can guide the environment (re-configure representations) and be guided by the resulting actions of the learning environment.
Navigation
The integration of dynamic visuals with meaningful haptic feedback forms should allow the learner to navigate the various attributes of the mathematical configuration and construct meaning.

Manipulation and Interaction
Objects in such learning environments should be manipulable, and deformed into a wide (if not infinite) set of similar objects, e.g., recall our triangle-area activity earlier; in such a setup all triangles can be configured through direct manipulation.
Variance/Invariance

Understanding how quantities vary or not under certain interactions allows a large wealth of mathematics to be explored. In addition to annotations such as measurement, linking variation to force feedback allows meaningful feedback to help guide the learner to make sense of important features, co-varying relationships or invariance.

Mathematically Meaningful Shape & Attributes

We naturally use touch to explore the composition of objects in nature as well as varying attributes. In addition to shape, form and texture, haptic feedback can be linked to attributes to aid the learner in their investigation.
Magnetism
A natural force is magnetism and this can be used to help learners focus on particular features or relationships between geometric shapes and surfaces. Some objects, or features of objects (where there is a particular mathematically-meaningful interest) can be magnetized and all other attributes de-magnetized.

Pulse/Vibration
Pulse in the form of vibro-tactile feedback or oscillating devices (such as the Omni) can similarly aid learners to focus their attention on certain parts of the activity, or offer some form of numerical feedback. For example, the frequency and amplitude of the pulse/vibration can be regulated to vary with some quantity.
Construction
Building on the affordances of dynamic geometry, allowing learners to use visual and haptic tools to construct mathematical configurations can help learners to make sense of what objects relate to each other (e.g., co-varying quantities) and communicate with others their understanding or production of a mathematical model.

Aggregation
Learning environments often have the affordance of wireless connectivity. Constructions, or evolving discoveries within the learning environment can be easily shared across networks as part of larger models to be aggregated on another computer, or to be contrasted with the work of other students working on the same project. Consider transferring a haptic force with a visual across a network where others can “feel” what you have felt.