Evaluating the Embodiment Benefits of a Paper-Based TUI for Educational Simulations

Tia Shelley
Computer Science
tshell2@uic.edu

Leilah Lyons
Computer Science, Learning Science
llyons@uic.edu

Emily Minor
Biological Sciences, IESP
eminor@uic.edu

Moira Zellner
Urban Planning and Policy, IESP
mzellner@uic.edu

Paper-to-Parameters

Paper-to-Parameters: low-cost, paper-based strategy to provide spatial input to educational complex systems simulations

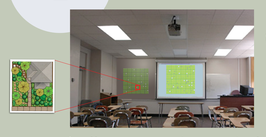
Problem space: learning about environmental science and the complex human-natural interactions

Task: incorporating green infrastructure into urban planning

Step 1

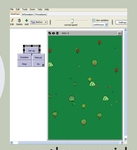
Students are provided stickers or paper cutouts bearing graphical symbols which represent elements in the simulation (e.g., particular species of plants or entire gardens, depending on level of scale).

Step 2



Students strategically arrange the symbols on a flat surface, like a sheet of paper or a classroom wall. A web camera is used to read the symbols and provide their coordinate information to the simulation.

Step 3

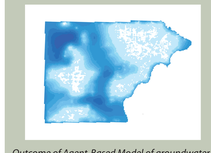


The simulation uses the provided coordinates to configure the spatial arrangement of simulation elements. The behavior of agents within the simulation is affected by the absolute and relative locations of these elements. Students can watch the simulation unfold via the classroom's projector and collect information on outcomes.

Step 4

Students use collected information on outcomes to further their understanding of how agents are affected by the simulation elements, and to inform further testing of spatial configurations of simulation elements.

Agent-Based Models (ABMs)



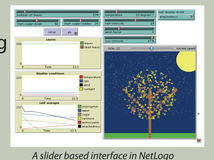
Outcome of Agent-Based Model of groundwater depletion (courtesy of M. Zellner)

Children using calculators to participate in a HubNet simulation

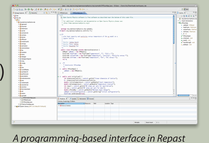
ABMs are frequently used in Environmental Science and Urban Planning to model the interactions of human behaviour and natural systems.
- Part of the authentic science practice that children should learn

Most ABMs designed for use by children lack convenient methods for specifying & manipulating spatial arrangement of simulation elements
- Graphical user interfaces typically rely on buttons and sliders
- Locations typically need to be programmed in

Prior work showed us that there is a large time savings using *PtP*(1m11s) over programming (8m 18s).



A slider based interface in NetLogo



A programming-based interface in Repast

Tangible User Interfaces (TUIs)

Embodied cognition theory and prior HCI work suggests that TUIs may be good for supporting:

Collaboration
Ability to communicate with partner
Ability to monitor partner's gaze
Simulataneous participation

Learning
TUIs more directly link cognition and perception than the traditional input devices

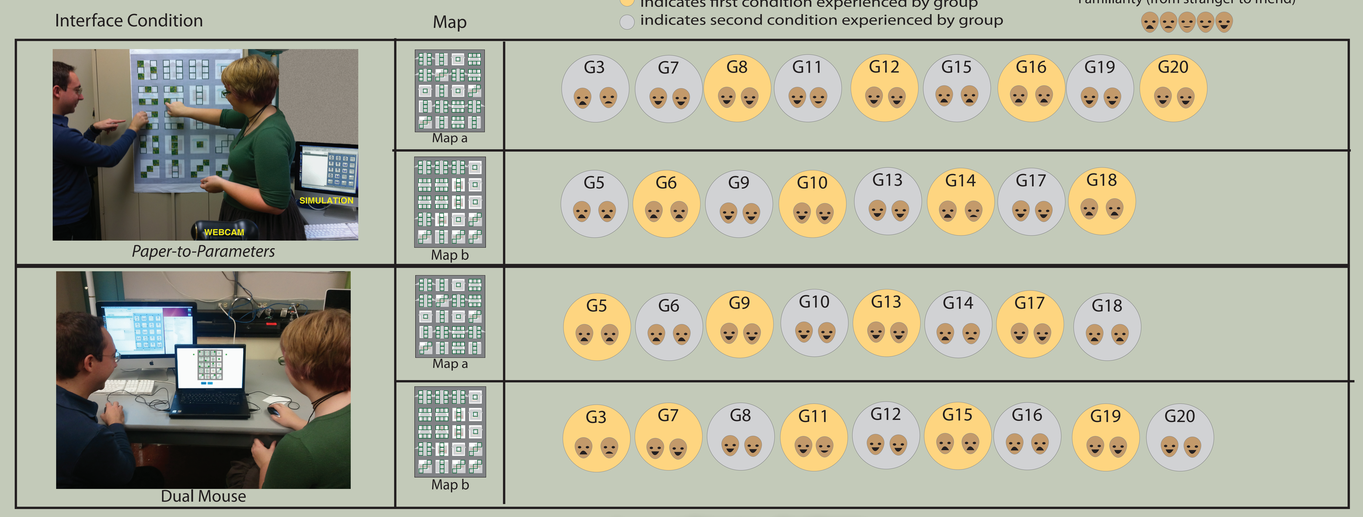
Spatial Tasks
No need to translate "I want to place that thing next to that other thing" into abstract coordinate system

Experiment

Need for study:
- Wish to build on prior work that makes claims about TUIs improving usability, problem solving, and collaboration
  - Many excellent qualitative studies, but not many controlled experiments

Study design:
- Built a dual mouse drag-and-drop interface as a control; need equal access opportunity
- Within-subject, 2x2 with rotation experiment, as indicated in illustration below

Data:
- Videotape
- Score log
- Record of configurations
- Post-study Likert questionaire on familiarity, usability & collaboration



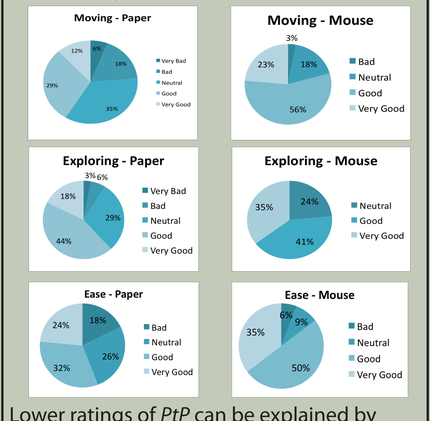
Results

Usability

H1: Faster Configuration Times with *PtP*

Average time spent per configuration:
No significant difference
Paper-to-Parameter: 1 minute 44 seconds
Dual Mouse:1 minute 38 seconds

H2: Higher Subjective Usability Ratings with *PtP*



Lower ratings of *PtP* can be explained by glitches in the computer vision system, rather than by the nature of the tangible interaction.

Problem Solving

H3. Faster Convergence on Best Solutions with *PtP*

Paper-to-Parameters

Dual Mouse

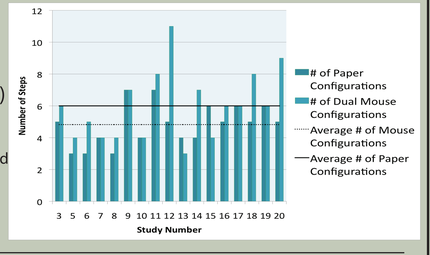
PtP resulted in a significantly faster convergence
t(17)= 2.58, p<0.02, single-tailed

H4. More Exploration with *PtP*

Users explored more intermediate steps using the dual mouse
Dual mouse: (M = 5.8)
PtP: (M = 4.7)

t(17)= 2.81, p < .02, single-tailed

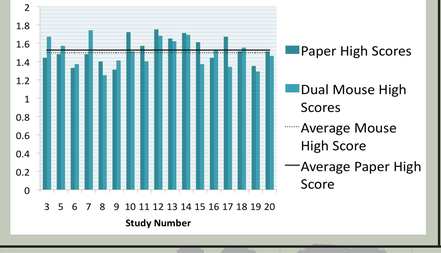
Probable explanation: computer vision read errors



H5: Users will get higher scores with *PtP*

Average High Score:
No significant difference

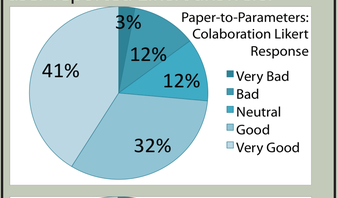
PtP: 1.525
Dual Mouse: 1.497

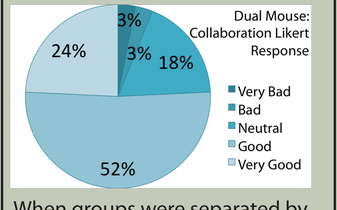


Collaboration

H6. Better Collaboration with *PtP*

Transcription and video analysis are forthcoming. For now, we have the user-reported Likert answers:





When groups were separated by familiarity, we found that 50% of acquaintances preferred to use *PtP* for control, while only 10% of friends did. This suggests that tangibles are more beneficial when there is no prior working relationship.