Spatial Experience, Technology, and Cognition

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Technology-Enhanced Learning in Science (TELS)
http://TELSCenter.org

Opportunities to Use Spatial Skills

Do visualizations contribute to learning?

www.concord.org
Scientists use Visualizations

World of Warcraft (WoW)

Teens use Visualizations

- Massively Multiplayer Online Role-Playing Game (MMORPG)
- World of Warcraft has over 10 million users worldwide (January, 2008)
- About the population of Sweden—and growing!


Teen Technology Use

Over half of online teens have a social networking site

Online Teen Activities

Predictions—Visualizations for Students

Visualizations contested

Most animated visualizations are no more effective than still diagrams. (Tversky et al., 2002).

Reflections and explanations can help (Chi, 2000; Davis, 2003).

Multiple representations help (Schwarz & White, 2005) or interfere (Johnstone, 1990).
Spatial Reasoning Trends

- Performance improving (Flynn, 2007 for Raven)
  - Role of video games (Feng, Spence, & Pratt, 2007)
  - Possible role for video design. U-Tube; MySpace; Facebook
- Gender effects declining
  - Gender Similarities Hypothesis (Hyde, 1999; Feingold, 1994, Voyer, et al. 1995)
  - Meta analysis (Lynn & Irwing, 2004; Irwing & Lynn, 2005)

Design for Knowledge Integration

- Students have repertoire of ideas (diSessa, 1988; Pfundt & Duit, 1994; Siegler, 2000, Vosniadou, 2007).
- Knowledge integration involves eliciting, adding, distinguishing, and sorting out these ideas (Linn, 1995, 2006; Latour, 1998; Thagard, 2000).
- Knowledge integration has an evolutionary character—powerful ideas survive.

Visualizing Airbag Safety

Students view video of crash test and conduct their own investigations to determine the conditions under which an airbag deploys safely. They link graphs of position, time, and velocity to experiments, and explanations.

See www.wise.berkeley.edu
Results Airbag Safety

<table>
<thead>
<tr>
<th>Condition</th>
<th>Pre</th>
<th>Post</th>
<th>ES</th>
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</thead>
<tbody>
<tr>
<td>Total (N = 90)</td>
<td></td>
<td></td>
<td>0.69</td>
</tr>
<tr>
<td>Magnet class (N = 22)</td>
<td></td>
<td></td>
<td>0.80</td>
</tr>
<tr>
<td>18% reduced price lunch</td>
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<td></td>
<td>0.96</td>
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<td>ethnically diverse (N = 12)</td>
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<td>31% reduced price lunch</td>
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<td>61% African-American (N = 9)</td>
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<td></td>
<td>0.67</td>
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<td>51% reduced price lunch</td>
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<tr>
<td>54% reduced price lunch</td>
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</tr>
<tr>
<td>95% African-American (N = 9)</td>
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Visualizing Global Climate

Students explore factors influencing climate change using a Netlogo model. They test the impact of adding CO2 and clouds and study the mechanisms.

See www.wise.berkeley.edu

Visualizing Chemical Reactions

Students explore how limiting and excess reactions work. They link unseen processes to symbolic representations and contemporary problems like accumulation of greenhouse gases.

See www.wise.berkeley.edu
Chemical Reactions Assessment

- TELS assessments ask students to link their ideas into an argument.
- In chemical reactions students illustrate understanding of limiting reactions.

Before Reaction

2S + 3O2 \rightarrow 2SO3

Draw the container after reaction.

Students made significant gains from pretest to posttest.

![Pretest and Posttest scores by group](image)

Regression with pretest, activity order, teacher, honors as explanatory variable, posttest as dependent variable ($R^2 = 0.58, F(1,137) = 47.5, p < .01$).

Visualizations in Inquiry Modules

Typical versus Inquiry Cohort

![Knowledge integration in science and math](image)
Visualizations and Gender HLM Analysis

<table>
<thead>
<tr>
<th></th>
<th>Full Model</th>
<th></th>
<th>Final Model</th>
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</thead>
<tbody>
<tr>
<td>Intercept (β₀(zero))</td>
<td>.43 ± .05</td>
<td>.43 ± .05</td>
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<tr>
<td>Level 1 (student level)</td>
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<td></td>
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<tr>
<td>Gender (γ_{gender})</td>
<td>.006 ± .04</td>
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</tr>
<tr>
<td>Level 2 (classes within teachers)</td>
<td>.01 ± .01</td>
<td>.01 ± .01</td>
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</tr>
<tr>
<td>Cohort [Inquiry versus Typical]</td>
<td>.06 ± .01</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>School Level</td>
<td>.003 ± .02</td>
<td></td>
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</table>

Science Cohort Comparison study.
There is a large and significant effect for visualization-based inquiry instruction across grades. The effect size is .32. There is no effect for student gender. The effect size approaches zero.

What contributes to success of modules?

- Critique investigation or explain connections?

+ Critique group learned more about experimentation

Which activities are valuable?

Drawing versus interacting

Hydrogen Fuel Cell Cars
Drawing outperformed Interaction

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Drawing versus interacting

Hydrogen Fuel Cell Cars
Drawing outperformed Interaction

Spatial experience, technology, and cognition
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What do current findings say about visualizations?

- Science courses benefit from well-designed visualizations
  - Students need guidance to interpret complex visualizations
  - Design studies are identifying principles and patterns that help students learn
    - See Kali, 2006; http://design-principles.org
    - See Linn & Eylon, 2006

What Forms of Spatial Reasoning Are Important for Science Learning?

- Spatial reasoning is not unitary
- Even performance across measures of 3D rotation varies substantially
- Spatial reasoning must be combined with disciplinary knowledge to interpret scientific visualizations. Speed in interpreting material is generally not a factor.

How can we collaborate?

- Explore interactions between spatial intelligence and learning from spatial visualizations.
- Study more complex, classroom settings
  - TELS modules and assessments are free, customizable
    - See WISE.Berkeley.edu
  - TELS assessments have excellent psychometric properties, linked to TIMSS, NAEP
  - Use Scalable Architecture for Interactive Learning (SAIL) to support interoperability
Thanks to All!

Technology Enhanced Learning in Science (TELS)
- http://TELSCenter.org
- The modules are free at http://wise.berkeley.edu

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