Spatial Experience, Technology, and Cognition

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Research and Training in Spatial Intelligence
Northwestern University, Illinois
June 13, 2008

7/20/08

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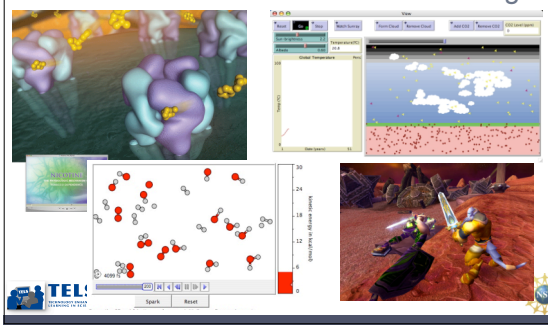
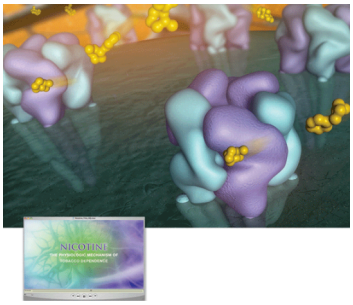
Opportunities to Use Spatial Skills

www.concord.org

Do visualizations contribute to learning?



Scientists use Visualizations



From: Science 2007 Visualization Winners. "Nicotine: The Physiologic Mechanism of Tobacco Dependence "(Hurd, J., DeSmet, D., Guerrero, J., & Tolentino, D.). http://www.sciencemag.org/cgi/content/full/317/5846/1858/F8.

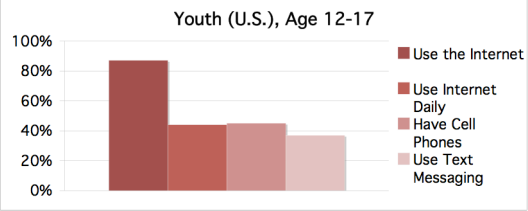
Teens use Visualizations

- 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!

World of Warcraft (WoW)

http://www.wowinsider.com/2008/01/22/world-of-warcraft-hits-10-million-subscribers/

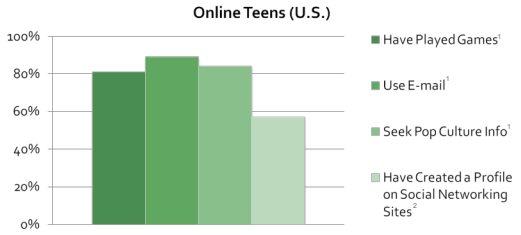
Teen Technology Use



Over half of online teens have a social networking site

Source: Lenhart, A., Madden, M., Hitlin, P. (2005, July 27). *Teens and Technology: Youth are leading the transition to a fully wired and mobile nation*. Washington, DC: Pew Internet & American Life Project. Available at: http://www.pewinternet.org/PPF/r/162/report_display.asp.

Online Teen Activities



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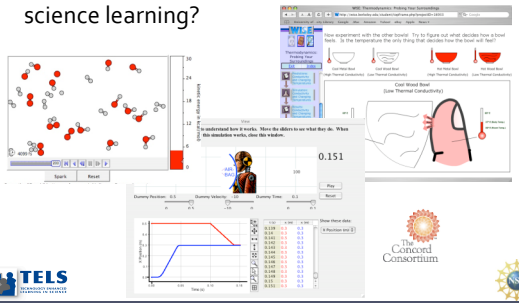
Source (2): Lenhart, A., Madden, M., McGill, A. R., & Smith, A. (2007, December 19). *Teens and Social Media: The use of social media gains a greater foothold in teen life as they embrace the conversational nature of interactive online media.* Washington, DC: Pew Internet & American Life Project. Available at: http://www.pewinternet.org/PPF/r/230/report_display.asp.

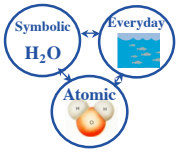
Predictions–Visualizations for Students

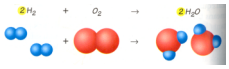
- How can dynamic visualizations improve science learning?



Visualizations contested

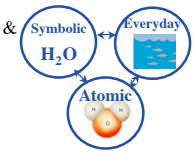
- Most animated visualizations are no more effective than still diagrams. (Tversky et al., 2002).
- Reflections and explanations can help (Chi, 2000; Davis, 2003).
- Multiple representations help (Schwarz & White, 2005) or interfere (Johnstone, 1990).



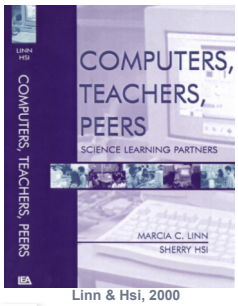


Spatial Reasoning Trends

- 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

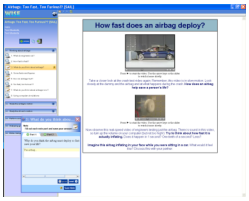


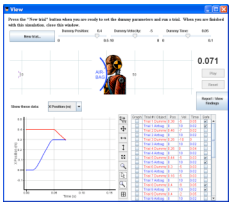
Linn & Hsi, 2000

- 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

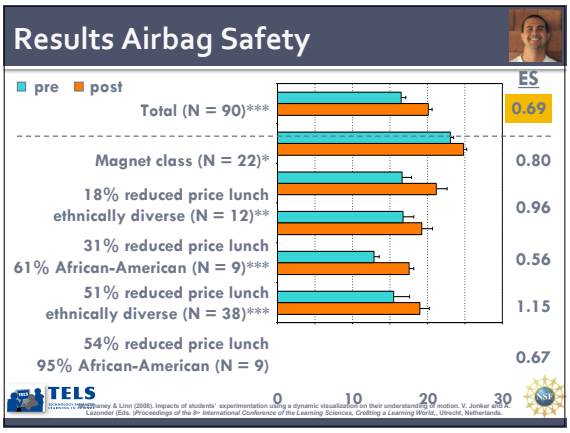
Kevin McElhaney

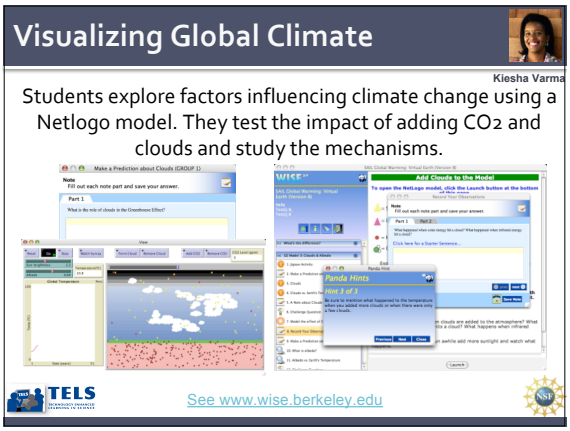


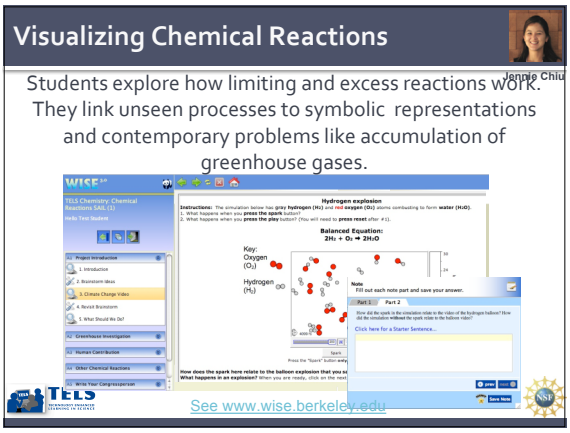


Students view video of crash test and conduct their own investigations to determine the conditions under which an airbag deploys safely. They link graphs of position, time, and velocity to experiments, and explanations.

See www.wise.berkeley.edu


Results Airbag Safety
pre
post
ES
Total (N = 90)***
0.69
Magnet class (N = 22)*
0.80
18% reduced price lunch
ethnically diverse (N = 12)**
0.96
31% reduced price lunch
61% African-American (N = 9)***
0.56
51% reduced price lunch
ethnically diverse (N = 38)***
1.15
54% reduced price lunch
95% African-American (N = 9)
0.67
0
10
20
30
TELS
Chaney & Linn (2008). Impacts of students' experimentation using a dynamic visualization on their understanding of motion. V. Jonker and X. Lazander (Eds.) Proceedings of the 8th International Conference of the Learning Sciences, Crediting a Learning World, Utrecht, Netherlands.


Visualizing Global Climate
Kiesha Varma
Students explore factors influencing climate change using a Netlogo model. They test the impact of adding CO2 and clouds and study the mechanisms.
TELS
See www.wise.berkeley.edu

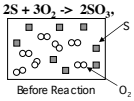

Visualizing Chemical Reactions
Jennie Chiu
Students explore how limiting and excess reactions work. They link unseen processes to symbolic representations and contemporary problems like accumulation of greenhouse gases.
TELS
See www.wise.berkeley.edu

Chemical Reactions Assessment

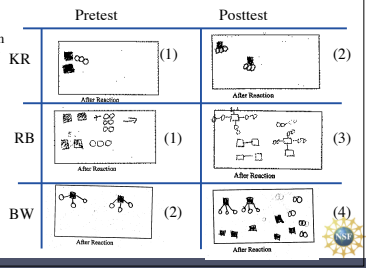
- TELS assessments ask students to link their ideas into an argument.
- In chemical reactions students illustrate understanding of limiting reactions.

Q. If only the molecules in the closed container below react according to the equation

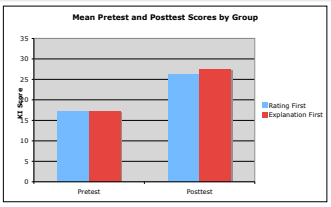
$2S + 3O_2 \rightarrow 2SO_3$,



Draw the container after the reaction.



Chemical Reactions Results



Regression with pretest, activity order, teacher, honors as explanatory variable, posttest as dependent variable ($R^2 = .58$, $F(4,137) = 47.5$, $p < .01$)

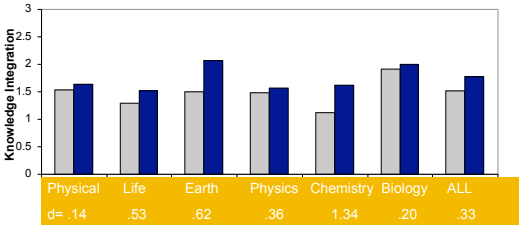
Students made significant gains from pretest to posttest

Students overestimate performance when view visualization without explanation.

Chiu, J. L. & Linn, M. C. (2008). Examining the Role of Self-Monitoring and Explanation Prompts on Students' Interactions with Dynamic Molecular Visualizations. International Conference of the Learning Sciences, Utrecht, the Netherlands.

Visualizations in Inquiry Modules

Typical versus **Inquiry** Cohort



Linn, M. C., Lee, H.-S., Tinker, R., Husic, F., & Chiu, J. L. (2006). Teaching and Assessing Knowledge Integration in Science. *Science, 313*, 1049-1050.

Visualizations and Gender HLM Analysis

Fixed Effects	Full Model Coefficient	Full Model *SE*	Final Model Coefficient	Final Model *SE*
Intercept (γ_{000})	.43	.05**	.45	.05**
Level 1 (student level)				
Gender (γ_{100})	.0006	.004		
Level 2 (classes within teachers)				
Cohort [Inquiry versus Typical]	.05	.01**	.06	.01**
School Level	.003	.002		

Science Cohort Comparison study.

There is a large and significant effect for visualization-based inquiry instruction across grades. The effect size is .32.

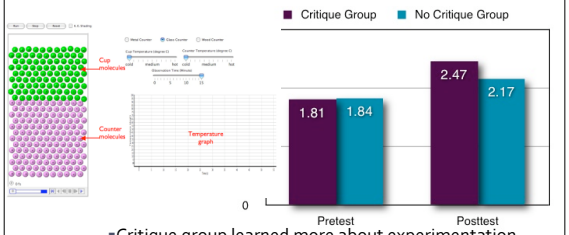
There is no effect for student gender. The effect size approaches zero.

Liu, Lee, and Linn, 2008. TELS, Visualization-based Inquiry.

What contributes to success of modules?

Hsin-Yi Chang

- Critique investigation or explain connections?



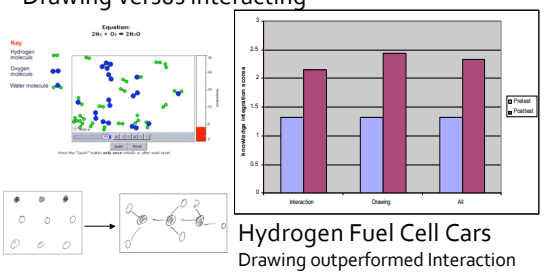
- Critique group learned more about experimentation ($t = 2.42$, $p < 0.02$)

Chang, H. et al. Visualizing Science. International Conference of the Learning Sciences, Utrecht, the Netherlands.

Which activities are valuable?

Helen Zhang

Drawing versus interacting



Hydrogen Fuel Cell Cars

Drawing outperformed Interaction

[t (131)=2.53, p=.01, ES=.45]

Chang, H. et al. Visualizing Science. International Conference of the Learning Sciences, Utrecht, the Netherlands.

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

Linn, M.C. & Eylon, B.-S. (2006). Science Education: Integrating Views of Learning and Instruction. In P. A. Alexander & P. H. Winne (Eds.), Handbook of Educational Psychology (2nd Ed., pp. 511-544). Mahwah, NJ: Lawrence Erlbaum Associates.

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

http://sail.sourceforge.net

Thanks to All!

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

TELS is supported by the National Science Foundation