Design Principles for Scaffolding Reflection and Argumentation in Science

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Knowledge Integration Environment

KIE Evidence

Galaxies in the Young Universe

by
other... Scientist

Scientists use telescopes to look at stars which are hard to see if we look just with our eyes. The picture below contains three images from a small region in the constellation Sculptor:

- On the left is a picture of the night sky taken with a camera, which is similar to looking up at the sky with your eyes. A small square is used to highlight a dark part of the sky where not many stars are visible.
- In the middle is that same highlighted part of the sky as seen with the Hubble telescope.
- In the upper right there is an enlargement of part of the middle picture.

http://www.kie.berkeley.edu/KIE.html
Basic Research Question

- What socio-cognitive scaffolds can help students engage in scientific critique and argumentation?
Defining “Scaffold”

- A support that helps learners engage in a practice or way of thinking they wouldn’t be able to do otherwise
- Wood, Bruner, & Ross (1976): one-on-one (human) tutoring + Vygotsky’s ZPD...
- … Our work: complex, technology-rich classroom systems
  - each component of the system is “designed” to do what it can do best
Two Sets of Studies

- Reflection Studies: What effect do reflection prompts have on students’ learning?

- Argumentation Studies: How can students be supported in coordinating scientific evidence with theory?
Three Reflection Studies

- Do students benefit from planning and reflection?
  - Group 1: Activity Prompts
  - Group 2: Self-Monitoring + Activity Prompts

- What effect does each prompt type have?
  - Group 1: Activity Prompts
  - Group 2: Self-Monitoring Prompts

- What role does specificity play?
  - Group 1: Directed (Self-Monitoring) Prompts
  - Group 2: Generic (Self-Monitoring) Prompts
Reflection Prompts

Thinking Ahead:
The information we need to include in our critique is...

Checking Our Understanding:
Claims in the article we didn’t understand very well included...

Generic Prompt:
Right now, we’re thinking...
Poor Reflection in Response to Prompts

Students who received directed prompts reflected poorly significantly more than did those who received generic prompts.
Students who received directed prompts and reflected poorly produced significantly worse critiques.
Coherence of Ideas

Students who received generic prompts developed more coherent ideas.
Summary of Reflection Results

- Generic prompts helped students add ideas to their repertoire and identify weaknesses in their knowledge... in this context and as compared to these directed prompts.
Argumentation Studies

- Investigate how students create, use, and learn from scientific arguments
  - Study individual learning, pair collaboration, and whole class discourse in the classroom
  - Study design and use of a knowledge representation software tool called SenseMaker

- Approach explored over 5 classroom studies
  - Final study investigated two alternative activity structures for argumentation
Prompt Students to Articulate Ideas

**ACTIVITY: Read Arguments**

**EVIDENCE:** Newton’s Blue Light Experiment

**CLAIM:** White sunlight is a mixture of different colors...

**Hints**

HINT FOR "Newton’s Blue Light Experiment": Can you come up with another way to explain Newton’s experiment?

ACTIVITY HINT: When you’re reading the arguments, pay close attention to what the scientists are saying. How are they using the evidence to support their ideas?

**Evidence Note:**

Rate the usefulness of this evidence in the debate and take notes about it:

- High
- Sort of High
- Medium
- Sort of Low
- Low
- (unrated)

What we want to remember about this evidence is... that Newton showed that blue light wasn't changed by putting it through a second prism. Kepler was wrong about light picking up color from objects.
Sample SenseMaker Argument

To Be Sorted...

 THEORY 1: Light Goes Forever Until Absorbed (LGF)
   A Little Light Poetry
   Light Spreads Out
     Searchlight Photo
     Our Candle
   Light Gets Dimmer
     Light Intensity Over Distance
     Far-away Candle
     Robert in the Car
     The Soccer Field

 Telescopes Bring The Light Together
   Galaxies in the Young Universe
   Brian Star-gazes
   Our Eyes Aren’t Strong Enough
     The Human Eye and Glasses
     We look at stars

 Telescope Evidence
   The History of the Telescope
   How a Telescope Works
   The Hubble Space Telescope

 Light Detector Evidence

 THEORY 2: Light Dies Out (LDO)
   Stars
     Our Telescope

 Irrelevant

 How Light Is Measured
   Flashlight Data

 Colored Light
   Bicyclists at Night

 Sensors
   Vernier Light Sensor

COLOR RATINGS:
   High
   Sort of High
   Medium
   Sort of Low
   Low
   (not rated)
Scaffolds allowed students to coordinate evidence with theory using causal explanations (for the most part)

<table>
<thead>
<tr>
<th>Evidence Explanations</th>
<th>Mean</th>
<th>Std. Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage of Causal Warrants</td>
<td>79.5%</td>
<td>(15.7%)</td>
</tr>
<tr>
<td>Percentage of Descriptions</td>
<td>16.2%</td>
<td>(14.5%)</td>
</tr>
<tr>
<td>Percentage of Statements of Irrelevance</td>
<td>4.2%</td>
<td>(6.6%)</td>
</tr>
</tbody>
</table>

Total Explanations per group (out of 13): 10.3 (2.3)
Average Explanation Length (in words): 68.6 (34.7)
The framing activity structure for the project influenced students’ use of the explanation scaffold.

Interaction Bar Plot for Descriptive Effect: Condition * Debate Position
Error Bars: 95% Confidence Interval

One case was omitted due to missing values.
Summary of Argumentation Results

- Scaffolds allowed students to connect evidence to theory using causal explanations (for the most part)
- The framing activity structure for the project influenced students’ use of the explanation scaffold
  - the perspective-taking activity structure supported students theorizing and learning
Design Principles

- Speak to the pragmatic, but bridge to and from theory
- Ground design principles in empirical analysis—during and after enactment
- Develop principles to increase the likelihood of (not ensure) specific learning events
- Explore a continuum from localized to generalized principles. Generality of principles bounded by:
  - the nature of the learning phenomena
  - contextual features of the system
  - the design of the study and our analytical understanding of theoretical concerns and empirical effects
Design Principles about Reflection

- Encourage reflection
- Promote productive reflection, including true self-monitoring
- Provide generic prompts for reflection (*)
- Promote identification of weaknesses in students’ own knowledge
Design Principles about Argumentation

- Engage students in explaining and making connections between evidence and claims as part of the classroom community interaction.
- Use activity structure and software design to support a flow of inquiry, rather than lock-step use of tools.
- Engage students in incremental, long-term argumentation centered around articulation, collaboration, and refinement of ideas.
Synthesizing Design Principles

- Develop software components with discipline’s epistemic elements and practices in mind.
- A single software cognitive guide could accommodate different epistemic practices.
- For specific epistemic practices...
  - make expert thinking visible to students
  - make student thinking visible to selves, peers, and teachers
- Provide multiple, complementary scaffolds in the system to support multiple, complementary knowledge integration processes.
Issues about Scaffolding

- Is everything a scaffold? Do we all mean the same thing when we say scaffold? When is it a useful construct?
- Do we agree that there is a difference between tools and scaffolds?
- Is it necessary to be specific about the nature of the different types of scaffolds under consideration?
- Is all scaffolding beneficial?
- What do we give up by using scaffolds which necessitate having a specific educational target?
Issues about Design Research

- What are the forms of productive design principles? (diSessa, 1991)
  - How general should design principles be? How localized?
  - What contextual information is important to report as we make design principles a shareable product?
  - How interconnected are design principles within a system? What are the consequences for the diffusion of innovation?

- How can we accumulate design principles? And on what basis should we reconcile conflicting ones?
  - What is the possible life of a design principle?
For More Information

See our session’s website:
http://www-personal.umich.edu/~betsyd/scaffolding.htm

Or email Betsy Davis: betsyd@umich.edu