Eliciting Students’ Abstract and Multidisciplinary Thinking in a Design Review

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This work is based upon work supported by the National Science Foundation under Grant DUE #1348547 and DLR #1721054. Any opinions, findings, and conclusions or recommendations expressed in this paper, however, are those of the authors and do not necessarily reflect the views of the NSF.

The full paper can be accessed at: https://web.ics.purdue.edu/~spurzer/QuintanaPurzer_NARST20_Proceedings.pdf
Introduction

• An emergent body of literature that explores the integration of engineering design into science education highlighting benefits and challenges (Carroll et al., 2010; Crismond, 2001; Mentzer, 2014)

• Most of the prior research approach design as a pedagogy, as opposed to a disciplinary practice of engineering (Purzer & Quintana, 2019). We argue that these intersect in the context of education but we treat engineering with an epistemological framing.

• Engineering design is a multi-faceted task that requires making connections between the experiential world and the disciplinary and multi-disciplinary ways of thinking.

• Previous studies that have focused on understanding design practices and reasoning are typically conducted among professionals’ engineers and undergraduate students (Crismond & Adams, 2012)
The Aim of the Study

• Our study aimed to examine design reasoning of youth and strategies that help elicit such reasoning in middle school students.

  • What are middle school students’ semantic transitions between concrete-to-abstract thinking, disciplinary-to-multi-disciplinary reasoning

• We used the semantic dimension of the Legitimation Code Theory (Maton, 2013) as our framework
Legitimation Code Theory

Maton (2013)
Wolmarans (2016)
Dong, Maton (2014)

Density - disciplinary vs multi-disciplinary
Gravity - practical vs theoretical

Semantic Quadrants

(Quintana & Purzer, 2019)

**First Principles:** explanations based on abstracted principles in a specific discipline

**Complex Abstractions:** explanations that are multidisciplinary and abstracted

**Design Trade-offs:** explanations that use concrete clues but recognize multidisciplinary

**Experiential Observations:** explanations with the use of concrete clues

Quintana & Purzer (2019)
Data Sources

10 seventh grade students and 2 design reviewers participated in this study

Project introduced by the university team but let by classroom teachers ALL 7th GRADE STUDENTS

http://energy.concord.org/energy3d
## Data Analysis

<table>
<thead>
<tr>
<th>Label</th>
<th>Code</th>
<th>Definition</th>
<th>Sample student answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strong Density</td>
<td>SD++</td>
<td>Multi-disciplinary thinking and recognizing competing trade-offs in explanations.</td>
<td>“When my net energy reached -200 KWH, I started to focus on reducing cost by adjusting the light entering the house and the size of the walls.”</td>
</tr>
<tr>
<td>Weak Density</td>
<td>SD--</td>
<td>Single disciplinary focus.</td>
<td>“So, my first house was a rectangle, I selected a simple, common shape”</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>Simply facts or numeric answers without an explicit rationale.</td>
<td>“I put there three trees”</td>
</tr>
<tr>
<td>Strong Gravity</td>
<td>SG++</td>
<td>Reasoning is based on concrete clues, not linked to theory.</td>
<td>“…Yes, I changed the windows and the roof to mess around with the cost and try to see what affected the cost.”</td>
</tr>
<tr>
<td>Weak Gravity</td>
<td>SG--</td>
<td>reasoning is theoretical and remains abstracted</td>
<td>“Heat transfer is the movement of thermal energy from one thing to another”</td>
</tr>
</tbody>
</table>
Q4: “What made this one hit the magic?”

Oliver: “Well, I finally figured out that you can right-click stuff, and I changed the efficiency all the way to 20%, and that significantly. The other houses, I wasn’t trying as much I was more trying to figure out how the program worked and what was needed.”

Coded: SD-/SG++
Transition 1: Experiential to First Principles

**Q1:** I get a really nice design of the house as we were looking at. Can you tell me a little bit about what your steps were in making this house energy efficient?

**Tori:** Well I change the roof a lot because it was, the way it works, at first, I had the roof panels on the wrong side of the house, and then I had to move them that around a bit. I also tried to make it (the roof) flatter and other roof designs to see the way the sun reflected more.

**Q2:** So, when you say that your solar panel was on the wrong side, what do you mean?

**Tori:** “So, the sun, it wasn’t in the sunlight kind of...(Indistinct)”

Coded: SD--/SG--
Results

Transition 2: Experiential to Design Tradeoff

Transition 3: Experiential to First Principles & Design Tradeoff
## Summary

<table>
<thead>
<tr>
<th>Transitions</th>
<th>Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>No transition</td>
<td>Oliver</td>
</tr>
<tr>
<td></td>
<td>Will</td>
</tr>
<tr>
<td></td>
<td>Jessy</td>
</tr>
<tr>
<td>Experiential to First Principles</td>
<td>Tori</td>
</tr>
<tr>
<td>Experiential to Design Trade-offs</td>
<td>Lisa</td>
</tr>
<tr>
<td></td>
<td>Mike</td>
</tr>
<tr>
<td></td>
<td>Peter</td>
</tr>
<tr>
<td></td>
<td>Ryan</td>
</tr>
<tr>
<td>Experiential to First Principles to Design Trade-offs</td>
<td>Alex</td>
</tr>
<tr>
<td></td>
<td>David</td>
</tr>
<tr>
<td>Experiential to Complex Abstractions</td>
<td>None</td>
</tr>
</tbody>
</table>
Conclusions and Contribution

• Our analysis resulted in three types of transition and no-transition.
  • First Principles ←(1)→ Experiential –(2)→ Design trade-offs
  • Transition to Complex abstractions were not observed

• Review sessions play an important role in eliciting student thinking. They reveal thinking that is not visible at the surface.

• We speculate that the fluid transitions reflect better understandings
  • Experiential to first principles (strong disciplinary core ideas)
  • Experiential to design trade-offs (strong disciplinary practices)

• Future research can examine if “design review sessions” promote fluid transitions across the semantic quadrants
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Reminder about Engineering RIG Meeting Tonight

Monday, March 16, 2020
9:00 pm | Eastern Daylight Time (New York, GMT-04:00) | 1 hr 40 mins

https://purdue.webex.com/purdue/j.php?MTID=m89202196db9c2c44cd27858192ad43af

Meeting password: narst
Meeting number (access code): 641 299 349