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)

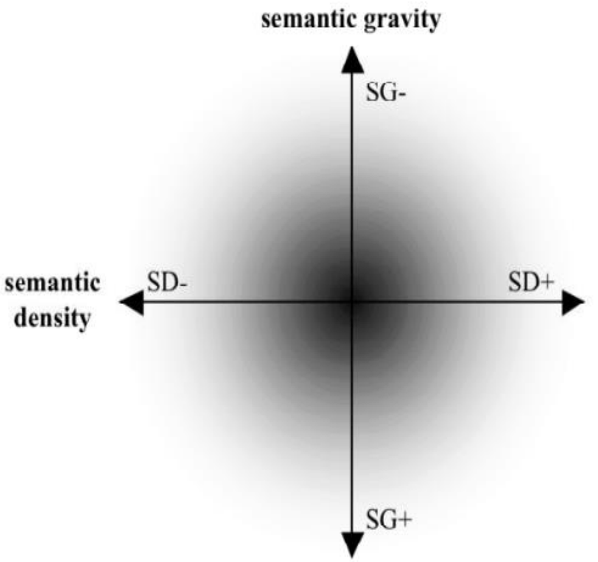
The Aim of the Study

- 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

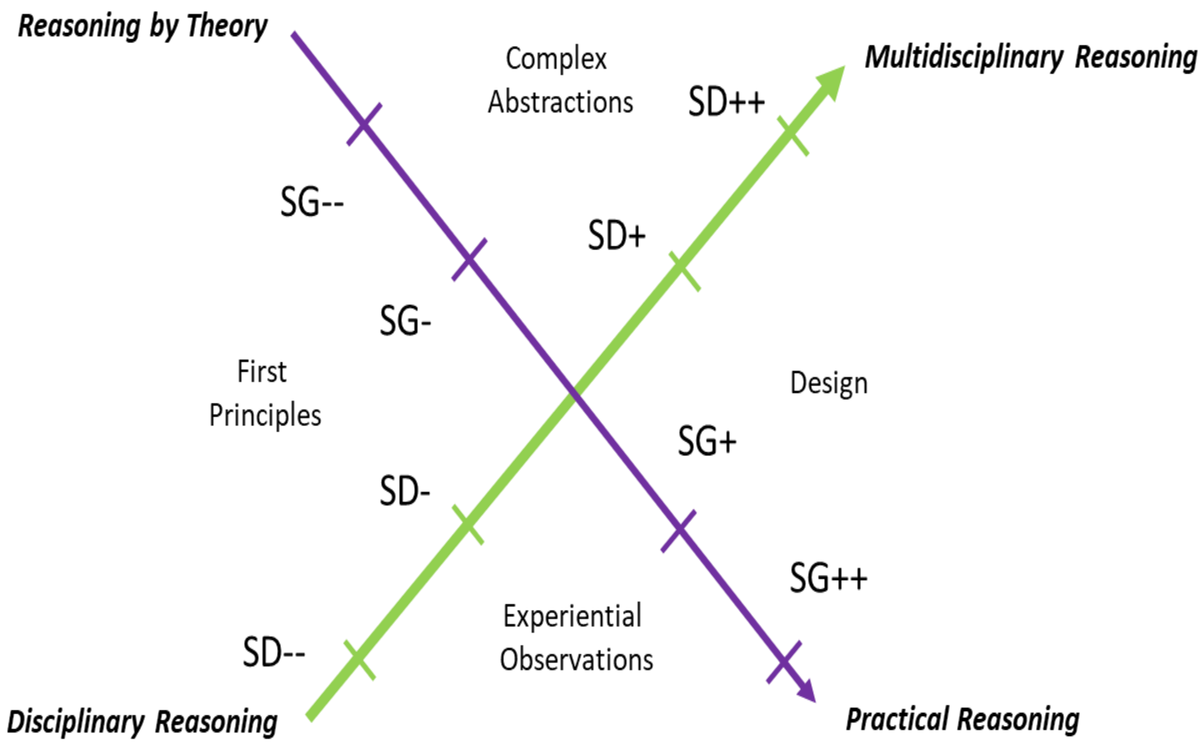


Maton (2013)
Wolmarans (2016)
Dong, Maton (2014)

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

Semantic Quadrants

(Quintana & Purzer, 2019)

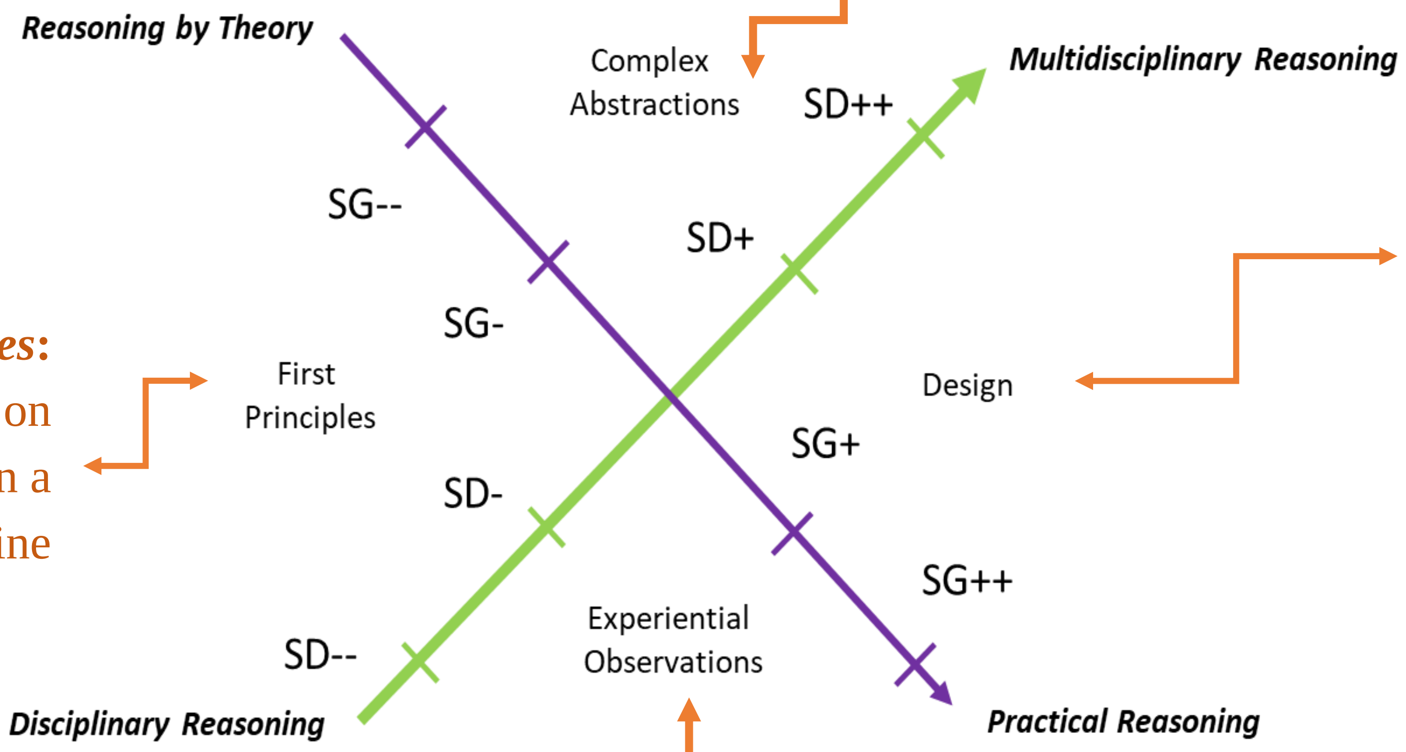


Quintana-Cifuentes, J. P., & Purzer, S., & Goldstein, M. H. (2019, June), Discourse Analysis of Middle School Students' Explanations during a Final Design Review (Fundamental) Paper presented at 2019 ASEE Annual Conference & Exposition , Tampa, Florida. https://peer.asee.org/32668

Semantic Quadrants Model

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

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



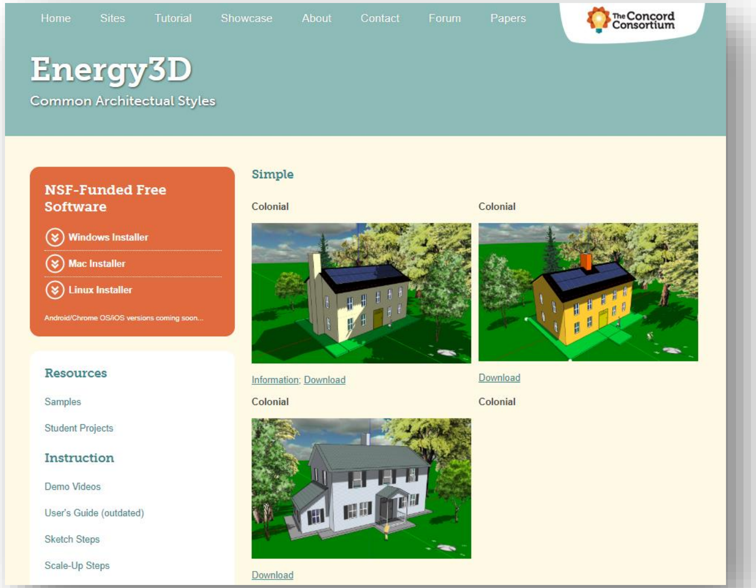
***Design Trade-offs*:** explanations that use concrete clues but recognize multidisciplinary

***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



http://energy.concord.org/energy3d

Design Challenge → Teacher Selection → 5-minute Student Final Presentation → Final Design Review with Each student → Transcripts of Design Review Conversations

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

Data Collection

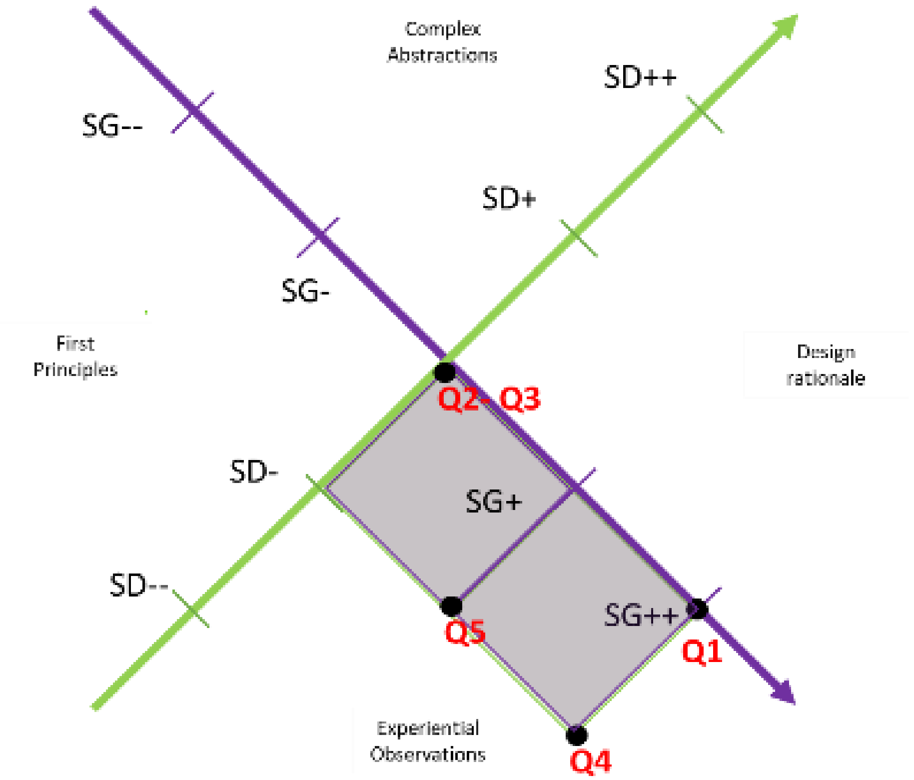
Data Analysis

Data Analysis

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

Results

No Transition Across Quadrants



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++

Results

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?*

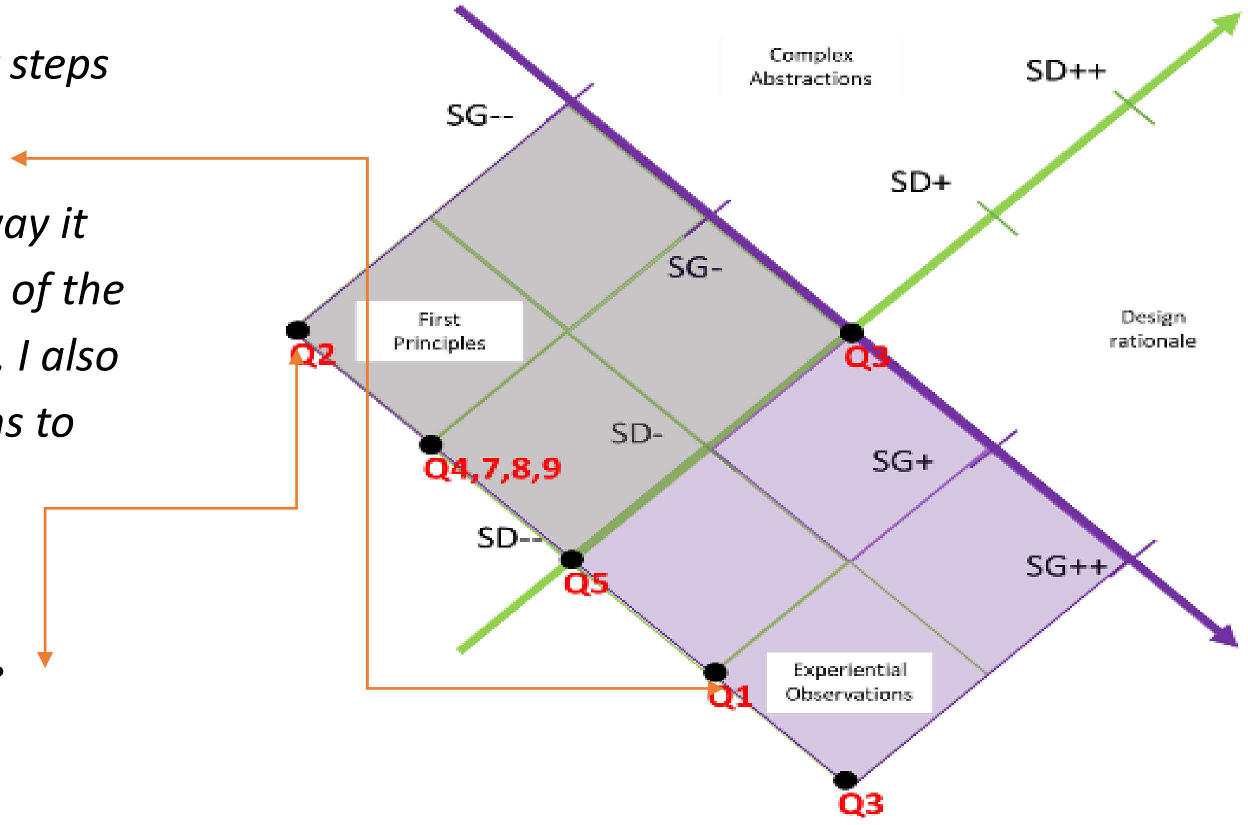
Tori: *Well I change the roof a lot because it was, the way it works, at first, I had the roof panels on the wrong side of the house, and then I had to move them that around a bit. I also tried to make it (the roof) flatter and other roof designs to see the way the sun reflected more.*

Coded: SD--/SG+

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

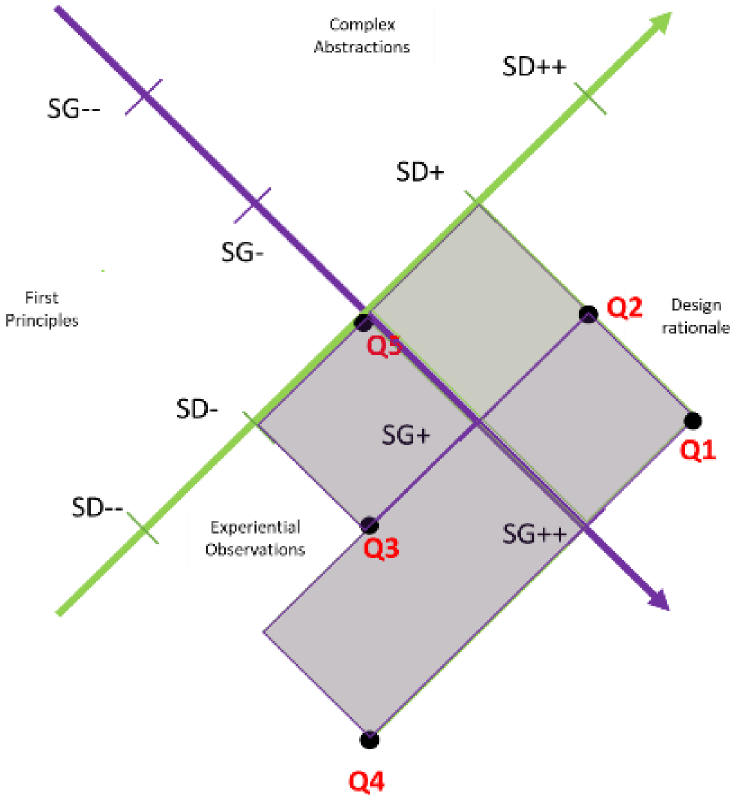
Tori: *"So, the sun, it wasn't in the sunlight kind of…(Indistinct)"*

Coded: SD--/SG--

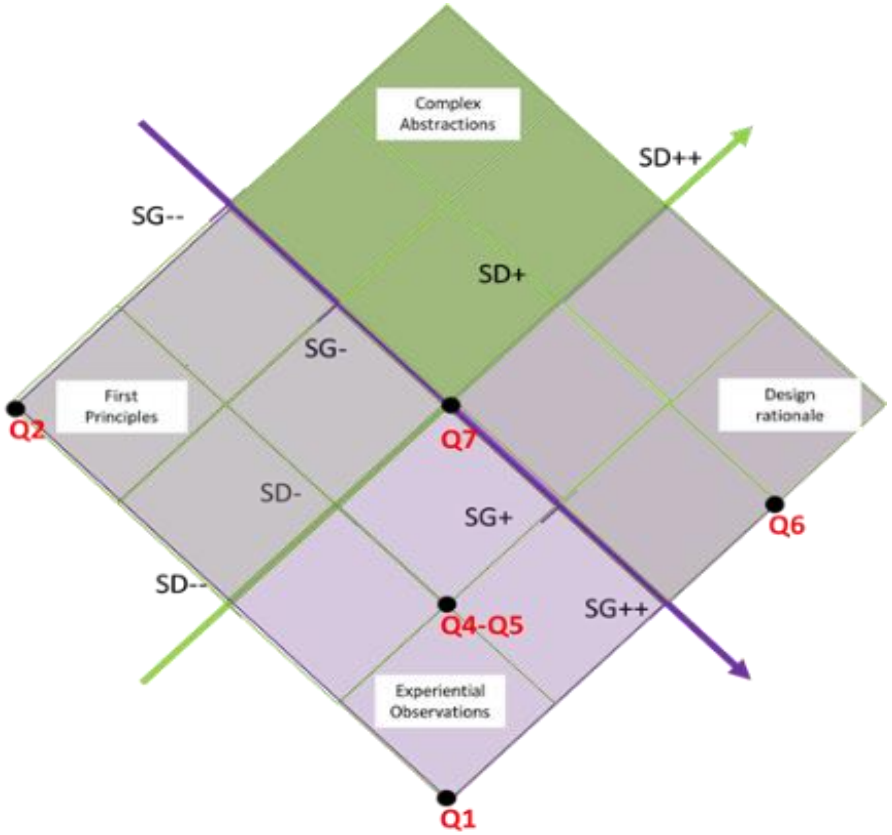


Results

Transition 2: Experiential to Design Tradeoff



Transition 3: Experiential to First Principles & Design Tradeoff



Summary

Transitions	**Students**
No transition	Oliver Will Jessy
Experiential to First Principles	Tori
Experiential to Design Trade-offs	Lisa Mike Peter Ryan
Experiential to First Principles to Design Trade-offs	Alex David
Experiential to Complex Abstractions	None

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

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