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LEARNING AND AGENCY THROUGH DESIGN NEGOTIATION: THE HONEYCOMB OF ENGINEERING

Parallel Session - 1.11 (Oral Presentations), 15:00-16:30 Monday, 28 August, 2023

Presenter Author 1291

ENGINEERING DESIGN COACHING TOOL FOR SUSTAINABILITY AND ETHICALLY-CONSCIENTIOUS EDUCATION

Parallel Session - 3.17 (Workshop), 09:00-11:00 Tuesday, 29 August, 2023

Table 1. Protocol for coding design reviewer questions and student answers into Design Reasoning Quadrants.

Code	Question Description	Question Examples	Answer Description	Answer Examples
Experiential Quadrant	The experiential questions elicit decisions on design features processes and prior experience used to make design decisions. These questions typically start with a statement, or an observation of a design feature to understand prior experiences with the design or processes.	"I also noticed that you don't have any trees was there a specific decision on that?" "Can you also elaborate on the location of the solar panels?"	Experiential answers describe specific features of a design experience-based decisions and steps followed when designing.	"So, a few of the first houses that I tried were basically rectangles, but I saw when I looked around the room, a lot of people were already doing rectangles. And I am not going to follow the trend…" "This here is about two meters, and then here is, I think, 4 meters. So, they're not super tall, but it worked out."
Trade-offs Quadrant	The trade-offs questions elicit multidisciplinary reasoning that facilitates balancing trade-offs. These questions start with a statement explicitly referring to competing design criteria associated with design requirements.	"So were there other things, other than aesthetics, when you tried to change the walls?" "… You mention in your thoughts what you learned. You talk about [being] realistic … and you needed to maximize your efficiency. What were some of your earlier versions of this house like?"	Trade-off answers demonstrate multidisciplinary understanding such as trade-offs necessitated by competing requirements and explaining risks and benefits, advantages, and disadvantages of design decisions.	"I had trees all around my house, and the walls were a lot taller, and I found that with all that together, it was getting really close to the budget, and it was going over when I was like adding solar panels and adding insulation. So, I ended up taking the trees away because when I did that, I found that helped drop my energy because they were shading the solar panels…"
First-principles Quadrant	First-principles questions elicit reasoning associated with disciplinary core ideas. These questions aim to elicit if students understand the underlying disciplinary concepts related to their design decisions.	"So, to follow up early, where you put the solar panel, so when, you know, when the sun moves from morning to evening. Which side of the house will get more of the sun?"	First-principles' answers use disciplinary core ideas to explain why design decisions were changed or developed in specific ways. These answers illustrate a theoretical understanding of discipline-specific concepts applied to design.	"I think a big part of getting the energy low is that I made sure that everything was insulated, including the windows. I tinted my windows black, and I made the colors of my house really light because color influences heat and temperature."
Complex Abstractions Quadrant	The complex abstractions questions elicit reasoning at the intersection of first-principles and trade-offs. These questions solicit reasoning in hypothetical situations in new contexts.	"Let me ask differently. Let us imagine you do not have any solar panels. Which one would you think will be a better design decision if there is not a solar panel? Having a big surface roof or smaller surface [area for the] roof?"	In complex abstractions answers, students imagine their design solution in a new way or a new context. In these answers, first-principles and trade-offs are intertwined along with imagined situations different than the one experienced.	"If my house design was located in a different city, where it heavily snows, I would consider improving and adjusting my thermal insulation, so the heat would be kept inside the house, and my heater will not be activated as often. However, the building would cost more. I would also need to evaluate if the solar exposure is sufficient enough to make up for the cost of the solar panels.
Clarification Questions	The clarification questions seek to clarify what student has shared such as numerical values.	"So, how high is this?" Then, how many windows do you have?"	Answers include replying to a previous question or providing descriptive, factual responses. These answers are also answers that do not provide enough information to evidence a type of reasoning	"Yeah, the surface area." "Yes, I did." "Maybe east?"

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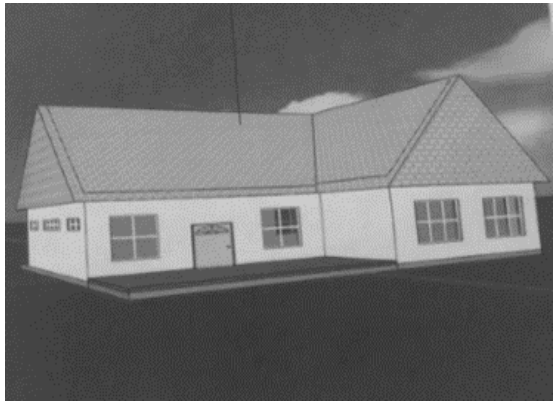
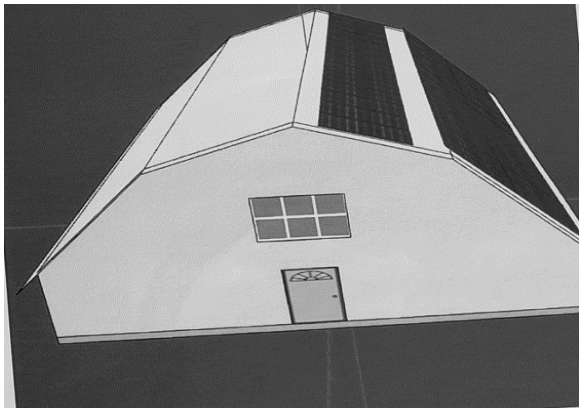
Ender's House



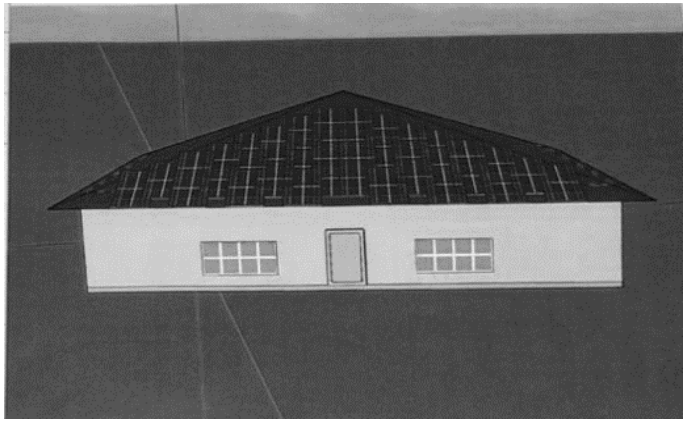
Size of the house: 188 m^2
Annual energy: -6580 kWh
Total cost: $236,416
Special features: Cut-out the front lawn, 2 car garage, 26 max efficiency solar panels

Lisa's House



Size of the house: 192 m^2
Annual energy: -32806 kWh
Total cost: $239,127
Special features: My house is full of special features. My yellow door attracts the eye to the front house. The farmhouse style is very unique, and eye catching…

Peri's House



Size of the house: 198 m^2
Annual energy: -13,175 kWh
Total cost: $222,229
Special features: Walls are monochromatic. The door stands out. You cannot see the solar panels from the ground, but if you were nine meters tall, they just blend into the roof. Short enough that you can retrieve whatever it is that your child just threw onto the roof. Tinted windows so that the floors (or rooms with windows) don't overheat.

Reviewer (Q1) "I like how you… describing your presentation that for you, this was a mix of traditional and modern. Really, I was struck looking at the house, it looks like one you could see in a neighborhood. What other kind of houses and shapes did you explore first?"

Mike (A1) "So, a few of the first houses that ***I tried were basically rectangles, but I saw when I looked around the room***, a lot people were already doing rectangles. And I am not going to follow the trend, so ***I based off of a lot of the houses in my neighborhood***. A lot of my house have the side garage and then they have different rooms to the left of the house facing. So, I explored a lot of designs, I even tried circle house, but it did not work out because the roof did not attach right. ***I decided on this one because it was more related, you know, it was familiar to me***.."

Reviewer (Q2) "Ok, very interesting, so it was again one way to look at the design. Did you look at the energy performance of the different homes?"

Mike (A2) "Definitely the circle one, because the roof on the circle one, it allowed a lot of sunlight to hit a lot of areas on the roof, and by ***putting a lot of solar panels down, I could maximize the efficiency,*** so it was around negative three, thirty-five thousand kilowatts per hours, ***but it looked like a muffin***, so I didn't really like that. So, basically, ***I came to a conclusion the more roof space that the sunlight hit, the more kilowatt per hours, the less kilowatt per hours."***

Reviewer (Q5-6) Question 5: "*So, let me ask differently. Let's imagine you don't have any solar panels. Which one would you think will be a better design decision if there is not a solar panel, having a big surface roof, or smaller surface roof?"*

Question 6: "And tell me why?

Mike (A6) ***"Because…I usually say the bigger the roof the bigger the house. I like big houses... I guess, I don't know how to put it."***

Reviewer (Q7) "So yes, it would actually…yes. Think about heat transfer and the possible impact."

Mike (A7) "*Oh yeah!! Yeah… the larger the* ***surface area in summer it could consequently make the roof very hot which can basically increase AC usage which is something that will…****Because in my first test that was actually one of the first issues the AC skyrocketed when up like nineties and in December drop.* ***So, I think actually both of them have disadvantages one of the disadvantages is AC usage, but the advantage more room for solar panels, so that the conclusion.***"

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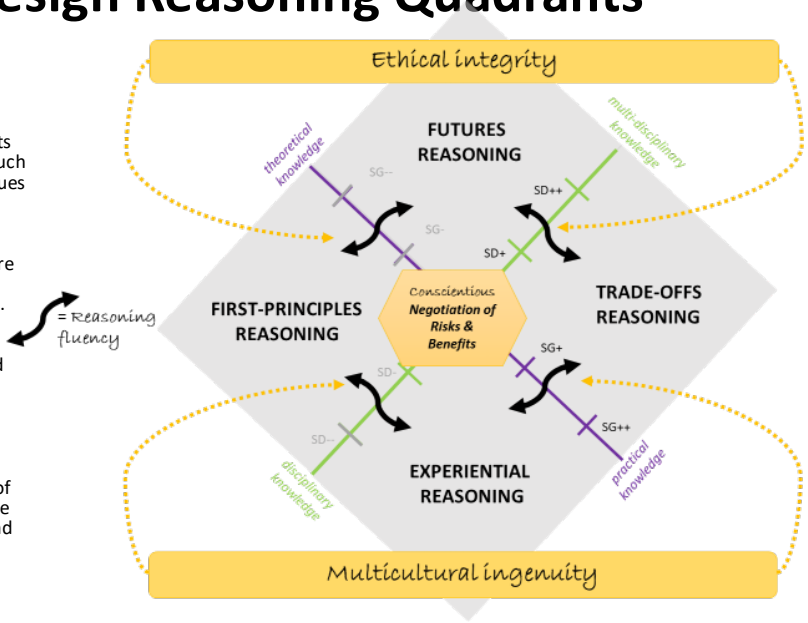
Engineering Design Reasoning Quadrants Framework

(1) ***Experiential observations*** represent reasoning based on new experiments as well as past lived experiences. Such reasoning can reflect subjective values or objective claims.

(2) ***First-principles reasoning*** represents thinking in terms of disciplinary core ideas that can be associated with science as well as other disciplines.

(3) ***Trade-offs reasoning*** entails the designer's multi-criteria thinking and efforts to optimize the design while weighing and balancing multiple competing design requirements.

(4) ***Complex abstractions*** reasoning enable predicting the performance of a design in a new setting and require the combination of first-principles and trade-offs reasoning (Quintana Cifuentes & Purzer, 2022).



Design Coaching Tool for Socially-Transformative Engineering Pedagogy

Experiential Questions elicit Multicultural Ingenuity

I am intrigued by ____, can you tell me more about this feature?

- Solar panel type, location, orientation
  - Roof, wall, freestandin
  - Cardinal direction
- Building shape, windows, doors
  - Roof style
  - Window size, location
- Location of trees
  - deciduous evergreen
  - Cardinal location

What has inspired this feature?

What is the purpose of this system? Who would use it?

Trade-Offs Questions

I heard you talk about ____, how about ____?

KWh produced, Appeal, Cost, Safety

You mentioned ____, and ____, how do they impact one another?

What are the advantages/ disadvantages of this? For example, when you lowered ____ did this impact ____ or ____?

First Principles Questions

You talked about ____/____, what's the application of (scientific, ethical) principle here?

If we defined ____ (theory/law) as _____, what would this mean for your design?

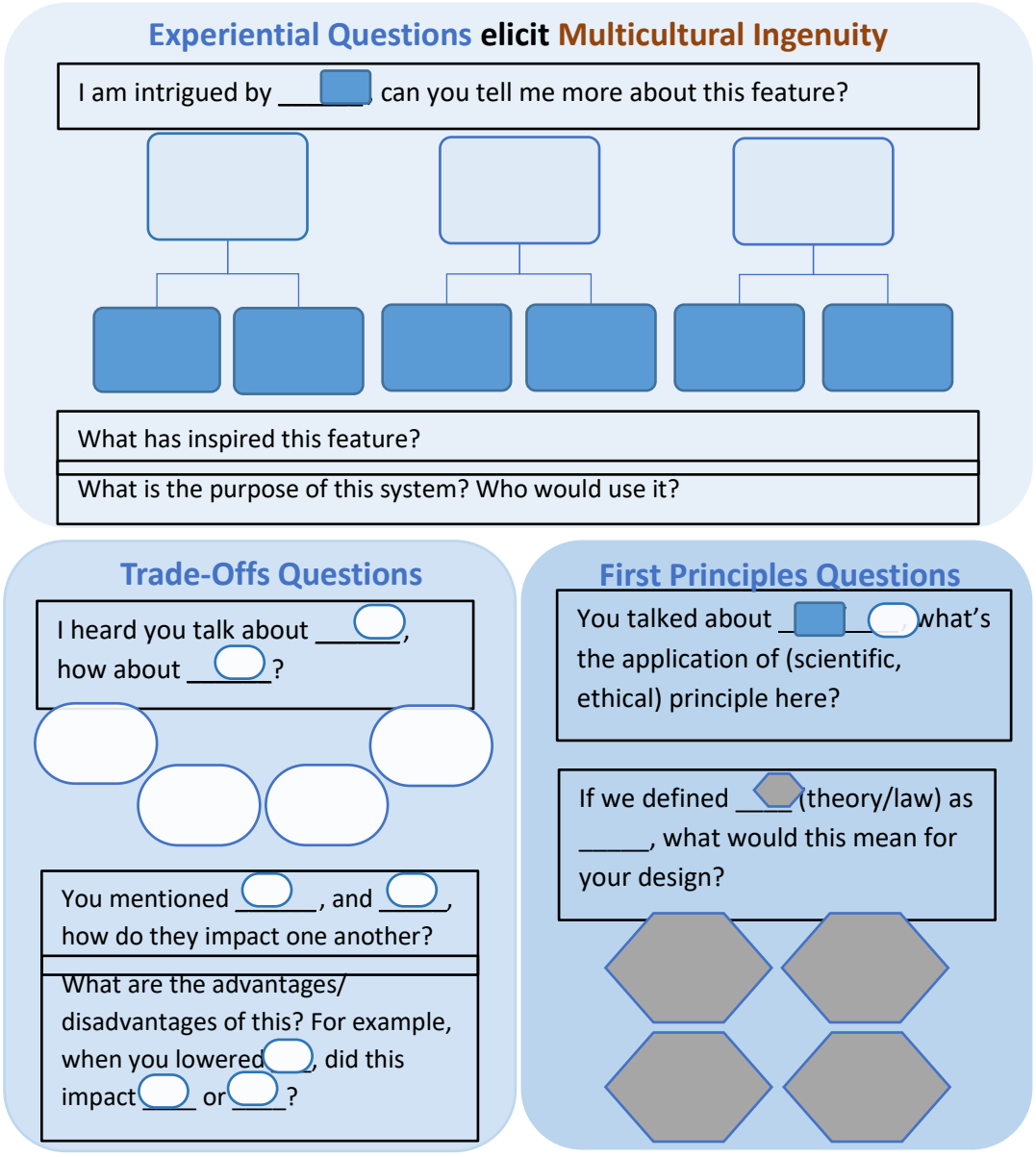
Solar path, Social values, Heat transfer, Aesthetic values

Futures Reasoning Questions model Ethical Integrity

Consider ____, how would your solution change with/without this aspect?

In 10 years from today, who would benefit from this design? Who might be harmed? How would this inform a re-design?

Design Coaching Tool for Socially-Transformative Engineering Pedagogy



Transformative AGENCY
designers are transformative agents through agency and ownership of their ideas and negotiation through first-principles and trade-offs

Reasoning FLUENCY
reasoning with practical as well as theoretical knowledge and disciplinary depth as well as interdisciplinary breadth towards a fluency across experimental reasoning, first-principles reasoning and, and futures reasoning

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