Exploring the role of disciplinary knowledge in engineering when learning to design

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Data: 3xME design teams

Prop Team

Robot Fish Team

Cap Team
Boundary crossing

“... purpose of this course ... integrating various engineering sciences into practical engineering design projects." (CP:p1)

“... fundamentals from these courses [statics, dynamics, thermodynamics, etc.] will be vigorously pursued ..."(CP:p3)

“...your obligations and expectations will not be as clearly spelled-out as in more traditional classes." (CP:p2)

Shift in pedagogic code:
- separated & explicit  \( \rightarrow \) integrated & implicit
- \( C+/F+ \)  \( \rightarrow \) \( C-/F- \)
Research questions

• How do students navigate the disciplinary boundaries and specialise knowledge into context in each design challenge?

• What is necessary in order to successfully apply scientific knowledge to solve design problems?
Finding the analytical concepts

“... purpose of this course ... integrating various engineering sciences into practical engineering design projects." (CP:p1)
“... fundamentals from these courses [statics, dynamics, thermodynamics, etc.] will be vigorously pursued ..."(CP:p3)
Semantic Gravity

The relationship between meaning and context
- **SG-**: meaning is *less* dependent on its context
- **SG+**: meaning is *more* dependent on its context

Process
- **SG\downarrow**: abstracting theory from a concrete context
- **SG\uparrow**: specialising abstract theory into a particular context

This is useful in two ways:
1. Rather than categorising knowledge as concrete or abstract, **SG relation between abstraction & the material object**.
2. **SG** a continuum of relative abstraction
   → a natural **movement up and down this continuum**.

Course Objectives: “fundamentals ...will be vigorously pursued”

Evaluative criteria: “...is it fully assembled? ... is it fully functional?”

(I: 'NO'-FDR-1:p1)
## Specialising SG to data

<table>
<thead>
<tr>
<th>Code</th>
<th>meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>SG--</td>
<td><strong>Theoretical</strong> abstraction <em>disconnected</em> from material artefact</td>
</tr>
<tr>
<td>SG-</td>
<td><strong>Theoretical</strong> reasoning <em>applied</em> to material artefact</td>
</tr>
<tr>
<td>SG+</td>
<td><strong>Practical</strong>/empirical reasoning <em>informed</em> by theoretical principles</td>
</tr>
<tr>
<td>SG++</td>
<td><strong>Practical</strong>/empirical reasoning ‘devoid’ of theoretical principles</td>
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"Our drive motor is now a geared motor... this will give us a little bit better mechanical advantage ... simpler assembly." ('PPP'-CDR:t2)

“several analyses to determine the size of the angle lead piece, and added a brace at the end... the key is that where the left motor is, the back plate was deflecting the rear quite a bit, but now it's in a range which is acceptable to us." ('PPP'-CDR:t4-5)
"And then the 1.6 you see above, is the wake. So during testing, this is gonna be one of the things we look for is actual wake... And this will show how we should get our approximate length of 11 inches." (‘NO'-CDR:t4)

C: Is that the vertical position of the center of buoyancy? ... So doesn't that mean that there's a fairly low margin to keep the fish upright?

S'NO: As far – well, it is weighted downward, so it should orient itself in this way, but it just won’t right itself as quickly. So the center of gravity is lower than that of buoyancy the moment will actually correct itself, right?

C: Right. What is that distance between the two? ...

S'NO: It was half-inch vertical distance.

C: Okay. So technically, that should right itself, right? But it's gonna be really slow ... So we might want to think about trying to increase that distance, that moment arm. (‘NO'-CDR:t14-15)

I: There it is on its side, rights itself well. Wow. That worked nice. Apparently, the calculations are good, too." 'NO'-FDR:t2)
"...plugging all the materials into Solidworks... working through the, torque equations ... we'll be running it at about .. 1½rps, ... about 32 lbf-in... some playing room to make sure that we can lift... " ('BC'-CDR:t10)

Sₐ: I was just wondering, so you’re rotating and lifting at the same time?
Sₜₜ: "Yeah, there'll be a ... slight lift ... once we start rotating the top."
Sₐ: "... how you're co-ordinating the two – rotating with lift "
Sₜₜ: "... that is done with two different ... stepper motors. So once the motor starts rotating, the other one would get signals like ... steps been completed. So lift this much... that had to come from the experimental data." ('BC'-CDR:t:13)

Sₜₜ: "... the lifting motor and the rotating motor will not lift or rotate. Um, they kind of just vibrate in place. ... We were able to get it to lift and rotate separately." ('BC'-FDR:t2)
Evaluation: SG++

"One, is it fully assembled? ...if it is not fully assembled ... what has changed and why? Two, is it fully functional? If it is not fully functional, what is not working and why" (I: 'NO'-FDR-1:p1)

• BC - S_{BC}: “but the lifting motor and the rotating motor will not lift or rotate. Um, they kind of just vibrate in place. ... We were able to get it to lift and rotate separately." ('BC'-FDR:t2)

• PPP - I: And **what did our top speed** end up being in this? S_{PPP}1: We did not measure it. I: What do we think it is? ... S_{PPP}1: Roughly two miles an hour, or – S_{PPP}2: **2 miles an hour.** I: What did we plan, 3.5, or something? S_{PPP}1: We had aimed for ... two miles an hour.
Evaluation: SG++

"One, is it fully assembled? ...if it is not fully assembled ... what has changed and why? Two, is it fully functional? If it is not fully functional, what is not working and why" (I: 'NO'-FDR-1:p1)

- I on NO: “...so you have it fully assembled, minus the issues that you talked about that give us like a B. And its not fully functional. ... I would decrease the scope of ...tracking. So ... virtually fully functional short of some efficiency problems, right? So by our algorithm, that gives you guys an A.

- PPP: "No, we don't need more time. It was not a critical function of our design." ('PPP'-FDR:t2)
DISCUSSION
Semantic Density

Semantic Density
• Condensation of meaning usually into symbolic form
• Integration of simpler concepts into a more complex whole

Discursive relations
• Relatively simple theoretical concepts, usually applied sequentially

Material relation
• the simpler the solution the better
• BUT what about necessarily complex problems that necessarily require more complex material solutions?

Relation between SD and SG
Implications for T&L design

• If knowledge matters in science based engineering, what sequence should we be teaching in?
• If we teach decontextualized concepts in subjects, how do we help students recontextualize into context?
• If engineers are expected to contribute to solving the complex global challenges, how do we reward necessarily complex solutions?
• Complex problems sometimes need solutions which demand more decontextualised reasoning, longer chains of inference.
A note on my methodology

Data
- Let the data speak
- Integration
- Ambiguity
- Complexity

Theory
- Relate to theoretical concepts
- Bernstein (C/F)
- LCT (Semantics)

Specialise
- External language of description
- semantic gravity
- semantic density (DR/MR)

Analyse
- Apply concepts to the data
- Categorise
- Causality