Revolution in Engineering Education

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Revolution in the School of Chemical, Biological & Environmental Engineering (CBEE) at Oregon State University

**Project Goal:**
We seek revolutionary change in the CBEE School through construction of a culture of inclusion and a shift in our learning environments from sequestered activities to meaningful, consequential work.
Evolution of a Revolution

Response to RED RFP drew from ongoing, individual efforts of CBEE faculty

provided funding, national community

Initial work by CBEE RED team....

Institutionalization of practices and structures to make it an ongoing CBEE project
A Systems Approach to the Professional Formation of Engineers
Cultural & Instruction
Inclusive teaming
Teaching innovation fellows
"Teaching 10" @ faculty mtgs
Alternating Leads

Curriculum & Instruction:
Vertical integration
Components of disciplinary knowledge
Studio 2.0

Changing Departmental Culture
Shift in position descriptions, tenure norms
Supporting International Students
Changing policies, norms and practices for workplace equity
Faculty Professional Development

Activity System

Year 4
Design-based research:
Ongoing assessment feeds design

Faculty interviews
Changed PDs

Annual student climate survey
Int’l student listening sessions
Exit interviews with graduating students
Student focus groups

Studio 2.0 Community of practice
Video studies of Studio 2.0
Curriculum committee documents

Ethnographic data
Curricular Reform

Figured worlds (Holland, et al) in engineering education

- Practices
- Norms
- Values
- Identities
Reform prior to Revolution

- Move to more active learning
- Including “Studio” sections for large lecture courses (~150-220)
  - Small group activities
  - Smaller (~30) sections
What’s the problem?

• Typical engineering school work uses de-contextualized problems with algorithmic solution paths
• Practices learned as part of school world
• Can lead to difficulty using these concepts to reason, debate or critically examine approaches and designs and
• Lack of transfer to engineering contexts
• Group work often dominated by one or two high-status students adept at school world
Studio 1.0 vs Studio 2.0 Design

Studio "2.0" reform in 11 core courses from “worksheeting” to “group-worthy” problems complex enough to benefit from multiple perspectives and understanding (Cohen & Lotan; Engle et al; Horn; Hammer et al, Pickering; etc.)

**Studio 1.0 (School world)**
- Students solving decontextualized problems with an expected path to get to a final “answer”
- Limited opportunity to express creativity and problem solving skills (Authority: Instructor)
- Bounded (School world)

**Moves Involved**
- Mostly forced

**Studio 2.0 (Engineering World)**
- Professional engineers tackling more open ended problems.
- Learners encouraged to work with group to come up with their own approach (Authority: student, engineering norms)
- Expansive (Engineering World)

**Framing**
- Expansive (Engineering World)

**Identities, activity, norms**
- Mostly forced
- Professional engineers tackling more open ended problems.
Increased uncertainty

Open-ended, contextualized problems are risky: increased student uncertainty and confusion

Instructors and students may resist change
Why might instructors & students resist change?

Engineering School (Post-secondary?) Norms

“Good” teaching → clear explanations →

Students who know how to solve our problems

Therefore,

Confusion in students is a sign of poor teaching or poor learning (Confusion = Bad! Scary!)
Why might instructors & students resist change?

When tasks are constrained

• Procedures are clear, less student confusion
• Resources localized to current course, chapter
• Everyone uses the same approach, so it is easy to monitor and troubleshoot – less uncertainty for both instructor/TA and students
Lab studies, classroom studies

Research question:
• How do student teams take up an engineering task designed for them to adopt roles reflective of professional engineers?
A case of confusion?

Michor, Nolen & Koretsky (2019) Destigmatizing confusion (ASEE)

Research questions:

• How do student teams take up an engineering task designed for them to adopt roles reflective of professional engineers?
• In what ways might confusion be a productive state of engagement towards forming engineers?
A Case of Confusion?

- Group of 6 second-year students in CBEE
- Week 7 of 10 in Material Balances course
- Graduate Teaching Assistant (GTA) and Undergraduate Learning Assistant (LA) facilitate group work
The task

- Design principles from Problem-Based Learning and Model-Eliciting Activities principles (Diefes-Dux et al. 2004, Woods et al. 1997)

- Students situated as process engineers at a candy production plant
  - Hydrolysis of sucrose to glucose/fructose mixture in acidic aqueous solution

- Asked to evaluate whether to implement a new process which would allow for higher conversion, but involve costly separation steps

INTEROFFICE MEMORANDUM

TO: ENGINEERING PROCESS DEVELOPMENT TEAM
FROM: BENITO BEAVER, VICE PRESIDENT OF ENGINEERING, BEAVER DAM SWEET TREATS
SUBJECT: PROCESS DESIGN RECOMMENDATION
DATE: NOVEMBER 9, 2016

We are excited about our high-volume, continuous manufacturing process design for our new Orange Candy product. This process will produce glucose ($\text{C}_6\text{H}_{12}\text{O}_6$) and fructose ($\text{C}_6\text{H}_{12}\text{O}_6$) via hydrolysis of sucrose ($\text{C}_12\text{H}_{22}\text{O}_{11}$) in aqueous solution (0.5 M HCl). These higher volumes will reduce cost and energy use. Your team will be responsible for final process design and startup.
Subtasks (from the handout)

- Share ideas on how best to work together.
- Sketch fully-labeled process flow diagrams comparing our current design with one utilizing the exciting new additive.
- Brainstorm specific engineering questions that need to be answered, then choose at least one and describe how you would recommend addressing it using the scientific process.
- Provide me [supervisor] any feedback you might have on my ethical approach to investigating this opportunity.
4 episodes

- Introduction and framing by GTA
- Teaming norms
- Flow diagram
- “Where does the HCl go?”
Teaming norms

Look for

• Participation/talk time (dominated, distributed)
• Any confusion? If so, about what?
• Engineering world or school world?
Flow diagrams

Look for

• Participation/talk time (dominated, distributed)
• Any confusion? If so, about what?
• Engineering world or school world?
“Where does the HCl go?”

Look for

• Participation/talk time (dominated, distributed)
• Any confusion? If so, about what?
• Engineering world or school world?
Our analysis: talk time

Teaming Norms

Flow Diagram

Where does the HCl go?

Fractional Talk Time

Time into Video (s)
## Our analysis: Episodic coding

<table>
<thead>
<tr>
<th>Code Category</th>
<th>Teaming Norms</th>
<th>Flow Diagram</th>
<th>Where does the HCl go?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Authority</td>
<td>Instructor</td>
<td>Instructor</td>
<td>Student</td>
</tr>
<tr>
<td>Participation</td>
<td>Dominated</td>
<td>Dominated</td>
<td>Distributed</td>
</tr>
<tr>
<td>Engagement</td>
<td>Worksheeting</td>
<td>Mixed</td>
<td>Engineering</td>
</tr>
<tr>
<td>Confusion</td>
<td>Inglorious</td>
<td>Minimal</td>
<td>Glorious</td>
</tr>
</tbody>
</table>
A role for confusion/uncertainty in inclusive environments

• “Glorious confusion” – uncertain how to approach a problem, space may open for alternative ideas, bringing in knowledge from outside the course, chapter

• This could contribute to more inclusive environments that require multiple brains and perspectives to make progress
A role for confusion/uncertainty in meaningful engineering work

Productive Uncertainty (Manz 2018)

Free & forced moves (Pickering, 1995)

Productive

Unproductive

Certain

Known forced moves?

Over-zealous transfer?

Dominance of “usual” participants?

Uncertain

Complexity + resources?

Complex problem with insufficient resources?

Free moves?

Fear of making mistake?
A role for confusion/uncertainty in meaningful engineering work

Productive Uncertainty (Manz 2018)

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Implications for revolutionary change?

• Radoff, Jaber & Hammer (2019) discuss learning to enjoy challenge and uncertainty as “meta-affective learning”

• How to increase *instructor* comfort with uncertainty?

• Can this kind of analysis help?
  – Evidence of more equitable participation
  – More realistic engagement (engineering world)
CBEE RED Team

Milo Koretsky
Michelle Bothwell
Devlin Montfort
Susan Nolen
Susannah Davis
Ed Michor

Past members: Christine Kelly, Jim Sweeney, Shane Lorona
Revolution in CBEE

Revolution in CBEE is a comprehensive programmatic initiative to make bold and deliberate changes to the educational environment and practices in the School of Chemical, Biological, and Environmental Engineering (CBEE) at Oregon State University (OSU). We have two related goals: (1) to create a culture where everyone in the CBEE community feels valued and belongs and (2) to create a learning environment that prompts students and faculty to meaningfully connect curricular and co-curricular activities.
Thanks!