How Prepared Are You?
Compare Your Engineering Skills With Other Graduating Seniors

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Acknowledgements

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What do engineering students know?

- Do engineering students **gather the information** they need to solve engineering problems?
- How do engineering students solve engineering **design problems**?
- Do engineering graduates define problems **broadly**?
- Do engineering graduates **integrate the concepts** they are learning – linking them to each other?
## Design Process Activities
Derived from analysis of 7 engineering texts

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<th>Design Activities</th>
<th>Design Stages</th>
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<td>Information Gathering</td>
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<td>Modeling</td>
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<td>Evaluation</td>
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<td>Decision</td>
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<td>Communication</td>
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<td>(Implementation)</td>
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<td>Project Realization</td>
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</table>
Experimental Design

- Participant groups
  - Freshmen (n = 26)
  - Seniors (n = 24, from CE, IE, and ME)
  - Experts / Practicing professionals (n = 19)
- Solved “Playground Problem” thinking out loud
- Asked experiment administrator for information while solving the problem
- Took 2 – 3 hours
Problem Statement: Design a Playground

You live in a mid-size city. A local resident has recently donated a corner lot for a playground. Since you are an engineer who lives in the neighborhood, you have been asked by the city to design a playground.

You estimate that most of the children who will use the playground will range from 1 to 10 years of age. Twelve children should be kept busy at any one time. There should be at least three different types of activities for the children. Any equipment you design must be safe for the children, remain outside all year long, not cost too much, and comply with the Americans with Disabilities Act.

The neighborhood does not have the time or money to buy ready made pieces of equipment. Your design should use materials that are available at any hardware or lumber store. The playground must be ready for use in 2 months.
Why a playground?
Verbal Protocol Analysis

1. **Record** audio from think-aloud protocol
2. **Transcribe** audio
3. **Segment** into codable “chunks” of subject statements (reliability check)
4. **Code** transcript (reliability check)
5. **Analyze** to answer specific research questions
Design Process Timelines

Freshman (Quality Score = 0.45)

|------------|------------------------|---------------------------|----------------------------|----------------|----------------------|---------------------|---------------|-------------------|
Activity Instructions

Individually, take a few minutes to answer Activity 1 on the worksheet:

- In the design process timelines shown on the worksheet, what similarities and differences do you see between the freshmen and senior engineering students?

- Do these similarities also involve the quality scores? How so?
Team Discussion

1. With your team, discuss your responses to Activity 1.

2. Where is your team in the design process? Where do you need to go?
Class Discussion
Our Findings: Freshmen vs. Seniors

Compared to freshmen, seniors...

- ...have higher quality designs. (whew!!)
- ...scope the problem more effectively by considering a broader range of information categories.
- ...make more transitions among design steps.
- ...spend more time iterating.
- ...progress farther in the design process.
Our Findings: Experts and Time

- Experts spend more time solving the problems in all design stages.
- Experts also tend to exhibit a ‘cascade’ pattern of transitions.
Our Findings: Experts and Information Gathering

- Experts “scope” the problem more effectively by…
  - …gathering more information than seniors and freshmen.
  - …covering more categories of information than seniors and freshmen.
Number of Information Requests and Categories

Freshmen = Seniors < Experts
\( (p = .137) \) \( (p = .048) \)

Freshmen < Seniors < Experts
\( (p = .035) \) \( (p = .028) \)
Information Categories for Playground Design

% participants

freshmen
- material costs
- handicapped accessibility
- material specification
- other
- body dimensions
- maintenance concerns
- technical references
- neighborhood demographics
- supervision concerns

seniors
- material costs
- handicapped accessibility
- material specification
- other
- body dimensions
- maintenance concerns
- technical references
- neighborhood demographics
- supervision concerns

experts
- material costs
- handicapped accessibility
- material specification
- other
- body dimensions
- maintenance concerns
- technical references
- neighborhood demographics
- supervision concerns
Additional Aspects of Design

Information Gathering and Context Focus

- Engineering design happens *in context*
  - Local, regional, national, global
  - Environmental
  - Social, economic, political
  - Technical

- Research questions:
  - What kinds of information do participants gather?
  - How do participants situate their designs in context, with respect to information gathering?
Context Focus of Information: Playground Studies

- **Broad Context Focus**
  - Body proportions
  - Information about the area
  - Neighborhood demographics
  - Handicapped accessibility
  - Safety
  - Legal liability
  - Neighborhood opinions
  - Utilities

- **Close Context Focus**
  - Availability of materials
  - Labor availability and cost
  - Material costs
  - Technical references
  - Budget
  - Maintenance concerns
  - Material specifications

- **Neither**
  - Supervision concerns
  - Other
Midwest Floods Study

- Vertical Protocol Study.
- Took from 20–30 minutes to solve the problem.
- Responses transcribed, segmented, and coded.
- 29 freshmen, 44 senior engineering students.

Problem Statement:
Over the summer [of 1993], the Midwest experienced massive flooding of the Mississippi River. What factors would you take into account in designing a retaining wall system for the Mississippi?
What factors would you take into account in designing a retaining wall system for the Mississippi?

<table>
<thead>
<tr>
<th>Factor</th>
<th>Broad or Close?</th>
</tr>
</thead>
</table>
Problem Scoping in Midwest Floods

- Physical location
  - Wall
  - Water
  - Bank
  - Surroundings

- Frame of reference
  - Technical
  - Logistical
  - Natural
  - Social
Context Focus and Problem Scoping Space

- social
- natural
- logistical
- technical
- no code

- close
- broad

- wall
- water
- bank
- surroundings
Examples of Broad and Close Context Factors

- **Social**
- **Technical**
- **Logistical**
- **Natural**
- **No Code**

- **Close**
  - “cost of materials”
  - “budget”
- **Broad**
  - “aesthetic appeal”
  - “surrounding habitat”

- **No Code**

- **Wall**
- **Water**
- **Bank**
- **Surroundings**
Our Findings: Midwest Floods

- Compared to freshmen, seniors engaged in broader, more extensive problem scoping.
  - Considered more factors.
  - Covered more of the problem scoping space.

![Diagram showing comparison between freshmen and seniors in problem scoping](image)
Our Findings: Information Gathering

- **Playground Studies:**
  - Amount of information gathered:
    - Freshmen = Seniors < Experts
  - Number of categories covered:
    - Freshmen < Seniors < Experts
  - Positive correlation between amount of information gathering and quality scores.

- **Midwest Flood Study:**
  - Seniors consider more factors when scoping the problem
  - Seniors consider more broad factors involving:
    - Physical location of retaining wall.
    - Frame of reference for the design task.
Team Discussion

With your team, discuss how you have considered broad and close context?
Additional Aspects of Design
Collaboration and Design

- Our previous studies focused on individuals doing the design process.
- In practice, engineering and design are often a collaborative effort.
- Research questions:
  - How does a group navigate the design process?
  - How does a group bring in and manage context during design?
A Team Designing a Thermal Pen Toy

- Early design and brainstorming of a thermal pen and media product for children.

- Seven engineers
  - Tommy: Electronics, Business Development
  - Patrick: Electronics and Software
  - Jack: Mechanical Engineer
  - Rodney: Industrial Design Student, Project Manager
  - Stuart: Electronics
  - Roman: Electronics and Software
  - Sandra: Ergonomics, Usability
Analyzing the Data

1. **Segment** provided transcript into codable “chunks” of subject statements (reliability check).

2. **Coded** transcript
   - Meeting Agenda Items
   - Topic of Conversation (including *group process*)
   - Design Activity
   - Context Focus

3. **Analyze** to answer specific research questions.
Design Process Timeline

- Shows beginning of “Cascade” from problem scoping to designing alternative solutions.
- If meeting had continued, project realization is expected to have occurred.
Context Focus

Code definitions:

- **Broad**
  - People / persons / users
  - availability of resources / parts to the end-users
  - marketing to the users
  - health, safety, environmental, social, or political concerns

- **Close**
  - technical components
  - features
  - budgeting
  - manufacturability of items or manufacturing of items


Context Focus Ratios by Episode

Episode I

Episode II

Episode III

0% 25% 50% 75% 100%

BROAD

CLOSE

APPLICATIONS

INTERFACE

ARCHITECTURE

BROAD

CONTEXT

February 2008
MSE 491 Classroom Presentation

Center for Engineering Learning and Teaching
University of Washington
http://depts.washington.edu/celtweb/
Findings: Everyone Considers Context

Number of Broad-Close Segments by Speaker
Findings: Attention to Group Process

Designers attended to the group process in two ways:

- Explicit statements or questions about the group discussion
  E.g. “We're kind of putting that to one side at the moment”
  “Oh- sorry can you go over that again?”
  “So do you think we've exhausted ourselves on what we can do with it?”

- Implicit utterances indicating understanding and support
  E.g. “Yeah”, “Okay,” and “Right”
## Everyone Does Group Process

### Number of Explicit-Implicit Segments by Speaker

<table>
<thead>
<tr>
<th>Speaker</th>
<th>Explicit</th>
<th>Implicit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tommy Rodney</td>
<td>1</td>
<td>8</td>
</tr>
<tr>
<td>Rodney</td>
<td>2</td>
<td>14</td>
</tr>
<tr>
<td>Stuart</td>
<td>2</td>
<td>32</td>
</tr>
<tr>
<td>Jack</td>
<td>7</td>
<td>88</td>
</tr>
<tr>
<td>Patrick</td>
<td>1</td>
<td>33</td>
</tr>
<tr>
<td>Sandra</td>
<td></td>
<td>26</td>
</tr>
<tr>
<td>Roman</td>
<td></td>
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</tr>
</tbody>
</table>
Team Activity

With your team, discuss how you have attended to the group process?
What’s Important

In addition to designing a quality product, engineers, need to attend to the processes of design:

- Gather information
- Consider context
- Attend to the group process
- …
Reflection Exercise

Please take a moment to answer the reflection questions:

- What was the most important thing that you learned today? Why?
- How can we improve this talk for future audiences?
THANKS!