Bringing Design Research into Engineering Classrooms

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Acknowledgements

Drawn from research by:

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CELT Design Research

- What do freshmen and senior students’ engineering design processes look like?
- What do experts’ engineering design processes look like, and how do they compare with students?
- When do students and experts gather information in the design process?
- How much and what kinds of information do they gather?
- How broadly do they scope design problems?
Engineering design is a systematic, intelligent process in which designers generate, evaluate, and specify concepts for devices, systems, or processes whose form and function achieve clients’ objectives or users’ needs while satisfying a specified set of constraints.

Session Agenda

- Present aspects of CELT’s Design Research.
- Interact with participants on possible implications for engineering pedagogy and student learning.
Playground 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
Why a playground?
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.
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 Activities
Derived from analysis of 7 engineering texts

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### Design Stages

- Problem Scoping
- Developing Alternative Solutions
- Project Realization
Design Process Timelines

Freshman (Quality Score = 0.45)

- PD: Problem Definition
- GATH: Gathering Information
- GEN: Generating Ideas
- MOD: Modeling
- FEAS: Feasibility Analysis
- EVAL: Evaluation
- DEC: Decision Making
- COM: Communication
Activity 1

Individually, take a few minutes to answer Activity 1 questions 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?
Discussion

- **Freshman #1 (Quality Score = 0.37)**
- **Senior One (Quality Score = 0.38)**
- **Freshman #2 (Quality Score = 0.45)**
- **Senior Two (Quality Score = 0.53)**
- **Freshman #3 (Quality Score = 0.62)**
- **Senior Three (Quality Score = 0.63)**
When asked the same questions seniors in a capstone design course reported:

- Everyone spent a lot of time on modeling.
- The people who spent time on multiple activities generally scored higher.
- The students who scored the highest did not spend large blocks of time on only one activity.
- Little time was spent on decision making.
- Seniors spent more time on feasibility analysis and evaluation.
- Seniors spent more time on project definition.
- For seniors, less continuous time spent modeling resulted in increased score.
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 activities.
- …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.
Information Categories for Playground Design

- material costs
- safety
- handicapped accessibility
- budget
- material specification
- information about the area
- other
- labor availability and costs
- body dimensions
- utilities
- maintenance concerns
- neighborhood opinions
- technical references
- legal liability
- neighborhood demographics
- availability of materials
- supervision concerns

% participants

freshmen

seniors

experts
Information Categories for Playground Design
Focus on Selected Differences

- Safety
- Handicapped accessibility
- Budget
- Information about the area
- Maintenance concerns
- Legal liability

% participants

0% 20% 40% 60% 80%

Experts
Seniors
Freshmen
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
  \( p = .035 \)    \( p = .028 \)
Activity 2: Group Discussion

1. What are some possible implications for engineering education?

2. What are some ways that this might be used in the classroom?
Reference List


Reflection Exercise

Please take a moment to answer the reflection questions:

- What did you find most interesting or important? Why?

- How can this workshop be improved for future audiences?
THANKS!