Cross Case Analysis of Elementary Engineering Task - Preliminary Results
Problem Statement

- Increasing academic focus resulting in loss of designerly play including engineering (Zhao, 2012).
- High need for diverse STEM workforce (Brophy, Portsmore, Klein, & Rogers, 2008).
- Start at elementary (Cunningham & Hester, 2007):
  - Children natural builders
  - Motivating, increase STEM pipeline
  - Integrate math and science
  - Problems solving, modeling, collaboration
While much is known about the design processes of older students and experts, there has not been a thorough and in-depth study of elementary student design processes and it is unknown if and how the conclusions and recommendations of these studies apply at the elementary level.
Research Questions

- What do grade 2 student engineering design processes look like? Grade 6 students?
- How do grade 2 and grade 6 students’ engineering design processes differ? Are there specific design cycle pattern differences?
- What specific differences can be seen in the planning and drawing between grade 2 and grade 6 students?
- How does causal reasoning differ between grade 2 and grade 6 students?
- For all these questions, are there differences that can be seen by gender at each grade level? LEGO Experience? Engineering design proficiency?
Engineering design process model for this study
Conceptual Framework

- Problem Solving Task
  - type of
  - Open Ended Engineering Task
    - Designerly Play
    - Causal Reasoning
    - Problem Solving Skills
    - Engineering Design Process Skills
Methodology

- Qualitative, Cross Case, Cross-Sectional
- Semi-clinical video interview (Ginsburg, 1997)
- Talk aloud protocol (Ericsson & Simon, 1980)
- Filmed six second grade student and six grade six students doing same open-ended engineering task of amusement park ride with age-appropriate LEGO robotics materials and craft materials
- Qualitative and quantitative analysis of EDP and non-EDP codes and activity
Setting and Participants

- **Rural PK-6 school**
- **6 typical boys and 6 typical girls**
- **Students started in K with robotics curriculum**
  
  *(Heffernan, 2013)*
Data Collection

- Warm up task (roof) - rubric
- Programs
- Photos of prototype
- Design data for each prototype - today
- Video tape of sessions - will yield EDP and CR data - future
Data Collection Results

- 2 hours of warm task and 8.5 hours of main task
- Some challenges with subjects and videotaping
- Completed November-December
- Multiple “track” issues with building and talking
- Transcription, segmenting and time-stamping - pass 1 underway
Design Data Analysis - Independent

- Warm Up Task - time, function, process (rubric)
- Ride task - creativity, function, process (rubric)
- Design Data - #parts, time, use of different parts (motors, computer, crafts, sensors, gears, etc), stability, symmetry, scale
- Self Efficacy
Design Data - Dependent

- Gender
- Grade Level
- LEGO Experience
- Engineering Design Process
Design Data by Gender

- WU Time Rating
- WU Function
- WU Process
- WU Rating
- Time
- #Steps
- Creativity
- Function
- Process
- Rating
- Stable
- Symmetrical
- Scale
- Computer
- Crafts
- Direct
- Gears
- Pulleys
- Motor
- Sensor
- Planning
- Self Efficacy
- LEGO Experience

Male
Female
Design Data by LEGO Experience

LEGO Experience +
LEGO Experience -
Design Data by EDP+-

The chart illustrates data for various categories, with EDP+ represented in blue and EDP- in red. Categories include:
- WU Time Rating
- WU Function
- WU Process
- Time
- #Steps
- Creativity
- Function
- Process
- Rating
- Stable
- Symmetrical
- Scale
- Computer
- Crafts
- Direct
- Gears
- Pulleys
- Motor
- Sensor
- Planning
- Self-Efficacy
- LEGO Experience

The graph shows a comparative analysis of these categories between EDP+ and EDP-.
#Parts by Grade, Gender, LEGO Experience, and EDP+

![Bar chart showing parts by grade, gender, LEGO experience, and EDP+](chart.png)
Warm Up and Task Rating by Subject

GRADE 2

GRADE 6

WU Rating
Rating

Boy 06  Boy 07  Boy 08  Girl 06  Girl 08  Girl 09  Boy 03  Boy 04  Boy 05  Girl 03  Girl 04  Girl 05
EDP Vs SE by Subject

GRADE 2

GRADE 6

Process
Self Efficacy
Task Rubric Ratings by Subject

GRADE 2

GRADE 6

Creativity
Function
Process
Rating vs SE by Subject

GRADE 2
GRADE 6

- Boy 06
- Boy 07
- Boy 08
- Girl 06
- Girl 08
- Girl 09
- Boy 03
- Boy 04
- Boy 05
- Girl 03
- Girl 04
- Girl 05

Legend:
- Rating
- Self Efficacy
Big Ideas - Warm Up Task

- Correlated with main task
- Some found it hard to attend to both constraints
- Structural knowledge of structures important
G2 Patchwork
G2 Interior Walls
G6 Removable Roof
G6 Interior Walls
G6 Underneath Composite Pieces
Big Ideas - Main Task

- For overall design results (not in-depth EDP and CR):
  - EDP and LEGO experience important
  - Gender and grade level not significant
  - Seems to be some significant differences in CR that correlates to advanced and EDP and results
  - Programming not key
  - Crafts not used much
  - Symmetry and stability important differentiators; scale concerns seen especially with roof
Serial versus hierarchical building processes

Students’ ideas of ride different; students could fill in hard to build parts mentally (non-computerized rides and coasters, for example)

Parts first and idea first

Relationship between domain specific knowledge and CR

Students do not generally choose to use separate planning materials
Big Ideas - LEGO

- Structural knowledge of LEGO key connector pieces
- Differences with LEGO engineering from paper and pencil non-building tasks
Big Ideas - Methodology

- Talk aloud and clinical at the same time has some tradeoffs (richness of data, questions influence building)

- Sharing out caused reflection and changes
Girl 05

- Could easily build and plan at the same time; others struggled to build and talk simultaneously
- Seemed to use COV
- Figured out some math and science transfer issues, in one case, with teacher prompting
- 2 Microgenetic learning moments (math and science application)
Microgenetic Learning Moments (3)

- Gearing up vs gearing down
- Odd number of holes in beam, where to center it
- 01:14:55 (Number of rotations of geared up side)
[00:02:25] [RESEARCH] {no_activity}

[00:03:08] [PLAN] Boy 05: I have to first build the structure of it. [IMPORTANT]

[00:03:12] [RESEARCH] {Searching}

Researcher: By structure, do you mean the part that holds up the moving parts?

[00:03:24] Boy 05: Yeah.

Researcher: What are you thinking? You picked out some parts.

[00:03:45] [PLAN] Boy 05: {no_activity}

[00:04:10] Boy 05: I think I'm going to have the base like this, and then have these holding this up. Actually, I think I might have it work like this, holding this up so this doesn't move back and forth.

[00:04:44] [BUILD-NORMAL] {connecting}

[00:05:01] [PLAN] {no_activity} Boy 05: I'm going to add these so they can connect.

[00:05:11] [EVALUATE-PHYSICAL] {moving} Boy 05: They don't fit properly.
EDP Timeline (Pilot)

EDP Phase Timeline - Grade 6

- Plan
- Research
- Build
- Program
- Evaluate
Non-EDP Codes

These will be tabulated and graphed by frequency and dependent variables
Next Steps

- Time-stamping and segmenting - pass 2
- Coding
- Update extraction programs
- Analyze EDP data
- Analyze non-EDP data
- Write results, discussion, summary
My Process

- Working full time as tech teacher
- Started courses in summer 2012
- Came in with research questions and teacher action research and clear desire and persistence to really understand elementary robotic
- Now have frameworks, previous research, and methodology to inform research
- Geared coursework and projects, when possible, to core questions
- Balance committee feedback with your own knowledge
- Kept reading and following lines of research, keep organized
Resources

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Kids Engineer - http://www.kidsengineer.com/

Elementary Engineering - Sustaining the Natural Engineering Instincts of Children