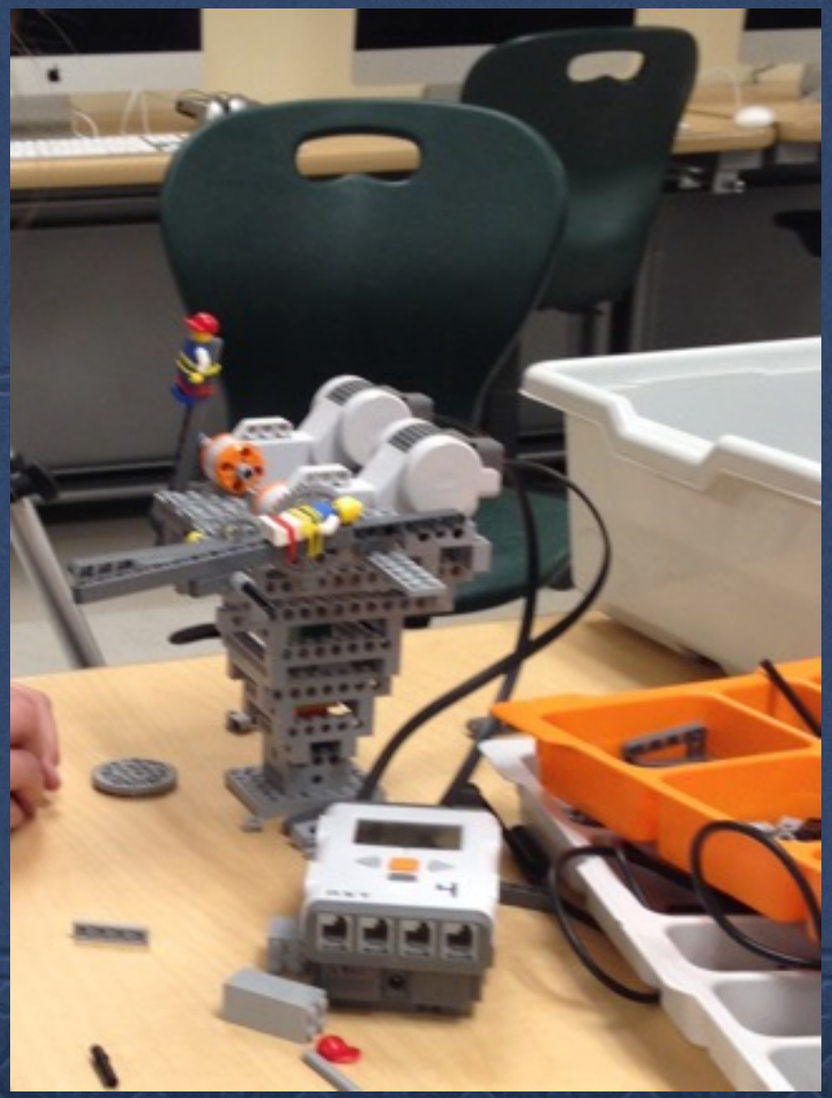
Cross Case Analysis of Elementary Engineering Task - Preliminary Results



John Heffernan

Problem Statement

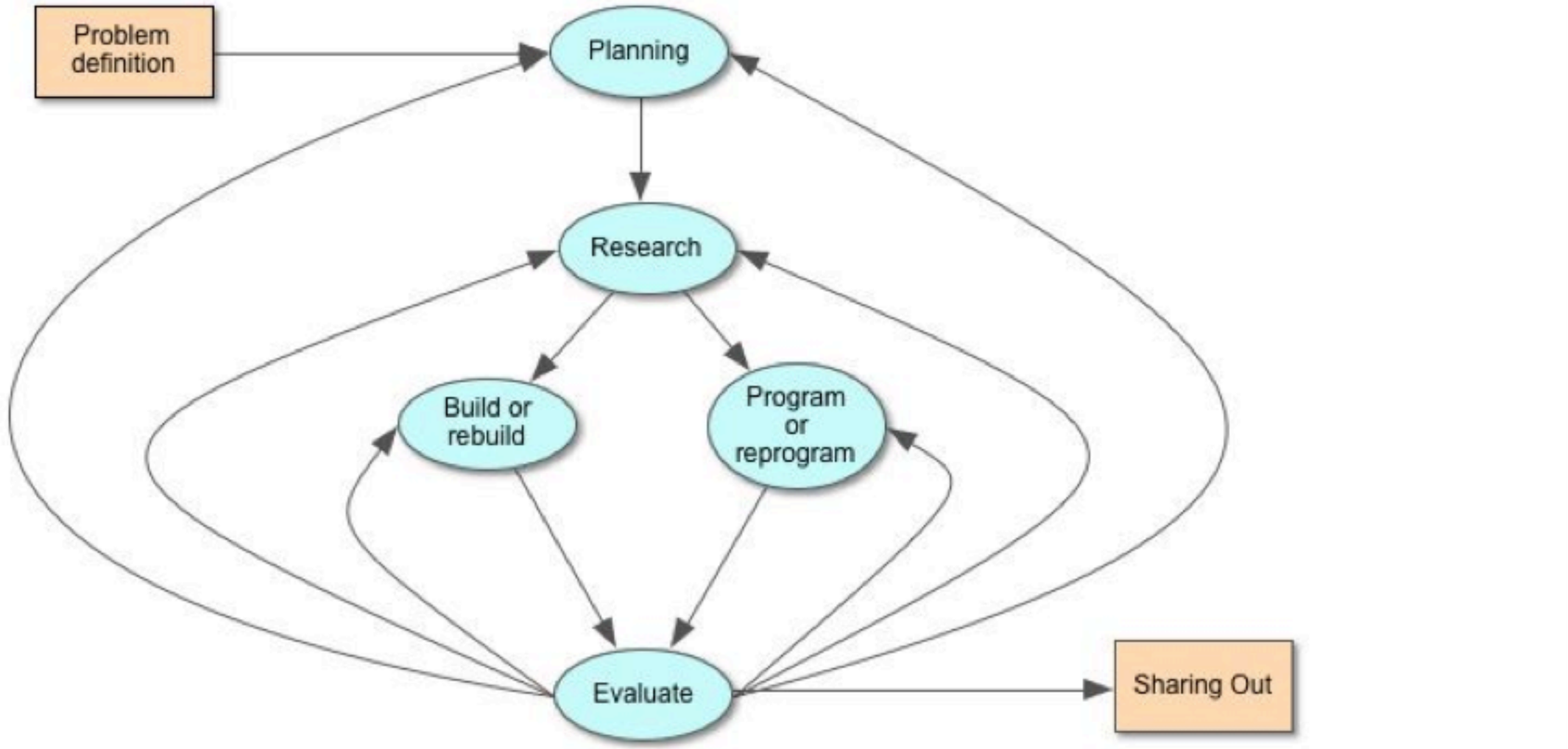
- *Increasing academic focus resulting in loss of designerly play including engineering (Zhao, 2012).*
- *High need for diverse STEM workforce (Brophy, Portsmore, Klein, & Rogers, 2008).*
- *Start at elementary (Cunningham & Hester, 2007):*
  - *Children natural builders*
  - *Motivating, increase STEM pipeline*
  - *Integrate math and science*
  - *Problems solving, modeling, collaboration*

EDP Research

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

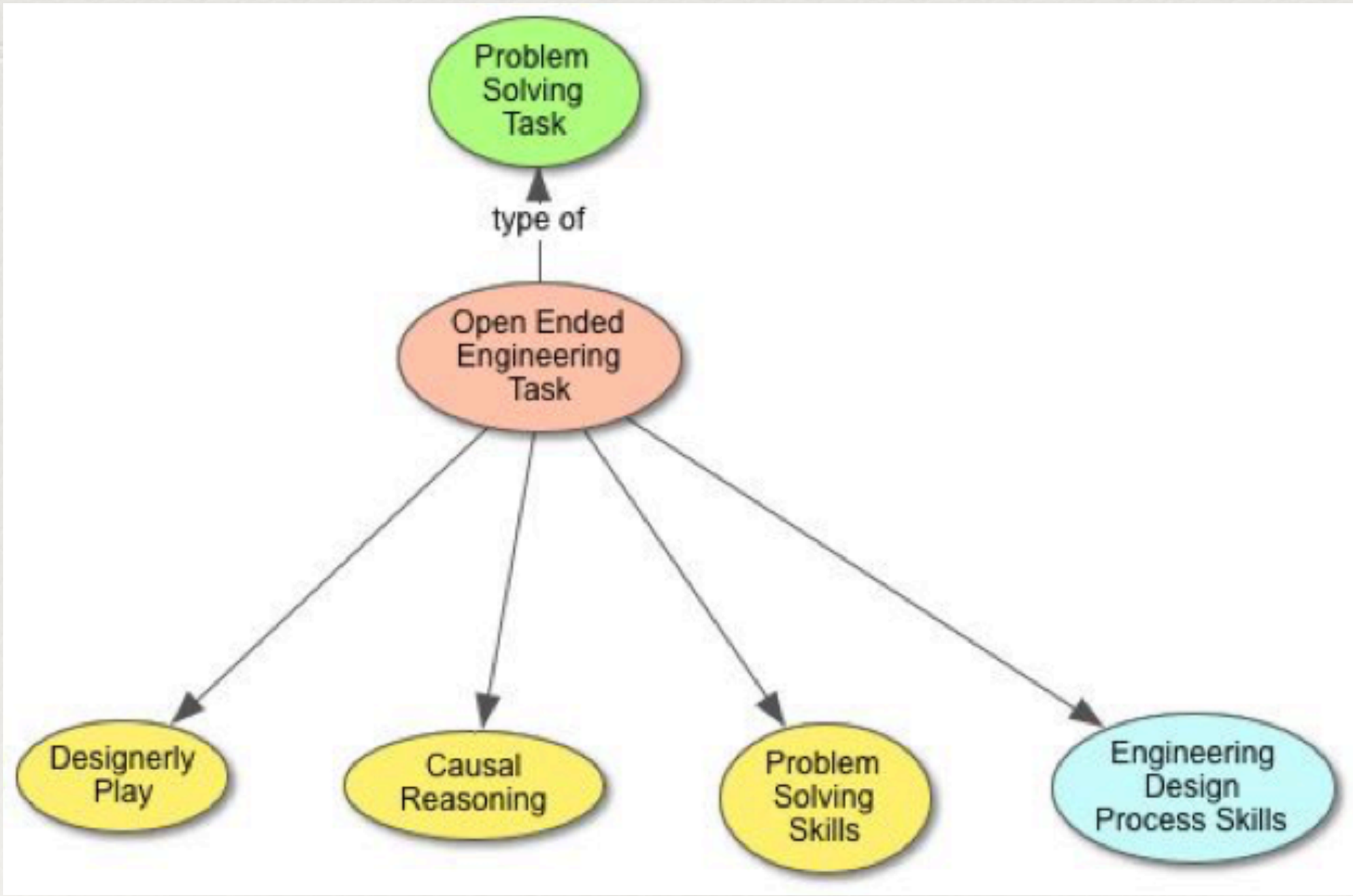
Research Questions

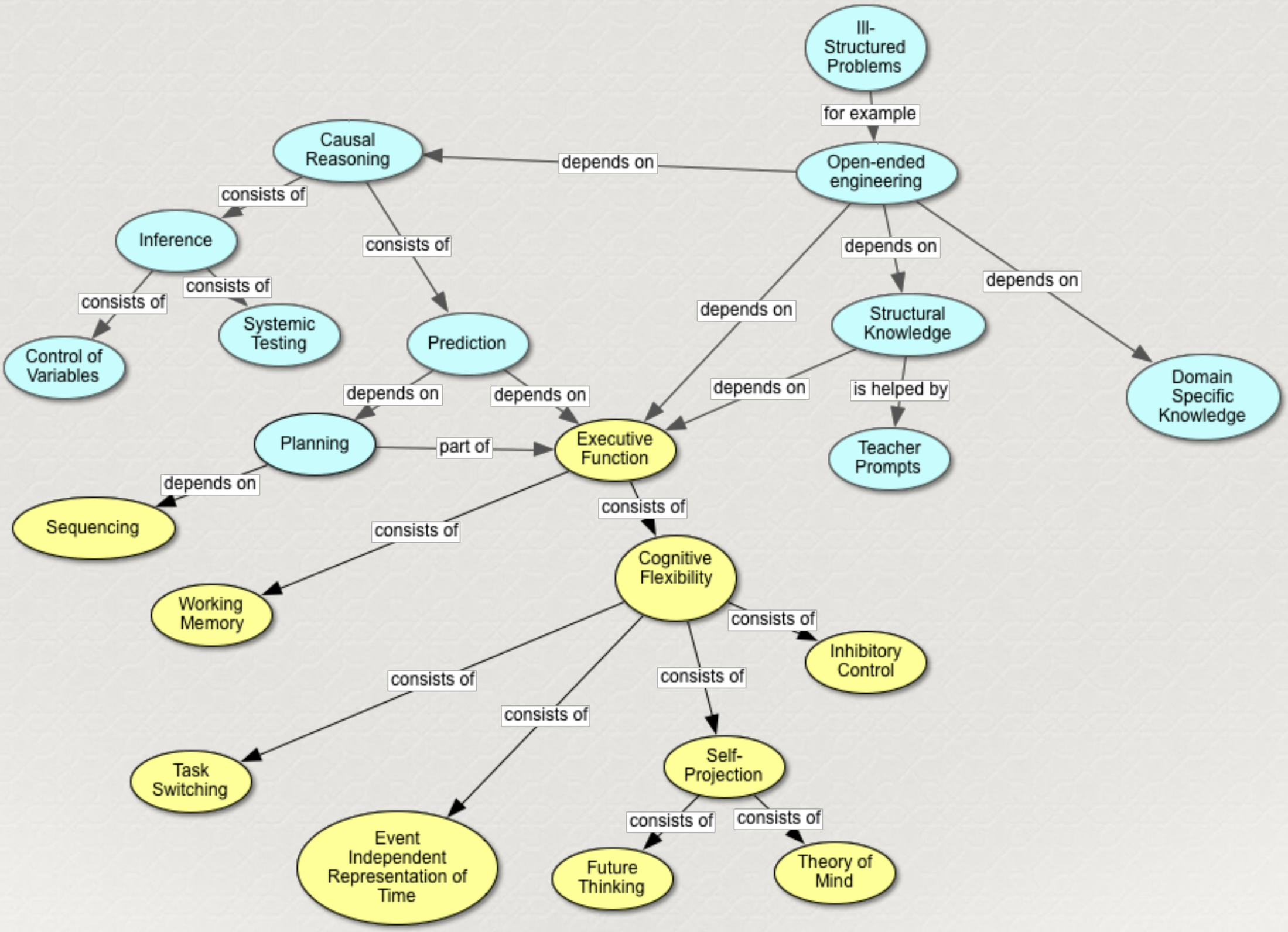
- *What do grade 2 student engineering design processes look like? Grade 6 students?*
- *How do grade 2 and grade 6 students' engineering design processes differ? Are there specific design cycle pattern differences?*
- *What specific differences can be seen in the planning and drawing between grade 2 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




Ill-Structured Problems
for example
Causal Reasoning
depends on
Open-ended engineering
consists of
Inference
consists of
consists of
Systemic Testing
consists of
Control of Variables
Prediction
depends on
depends on
depends on
depends on
depends on
Structural Knowledge
depends on
Domain Specific Knowledge
is helped by
Teacher Prompts
Planning
part of
Executive Function
depends on
Sequencing
consists of
consists of
Working Memory
Cognitive Flexibility
consists of
Inhibitory Control
consists of
consists of
consists of
Task Switching
Self-Projection
Event Independent Representation of Time
consists of
consists of
Future Thinking
Theory of Mind

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 quantitive analysis of EDP and non-EDP codes and activity*

Setting and Participants

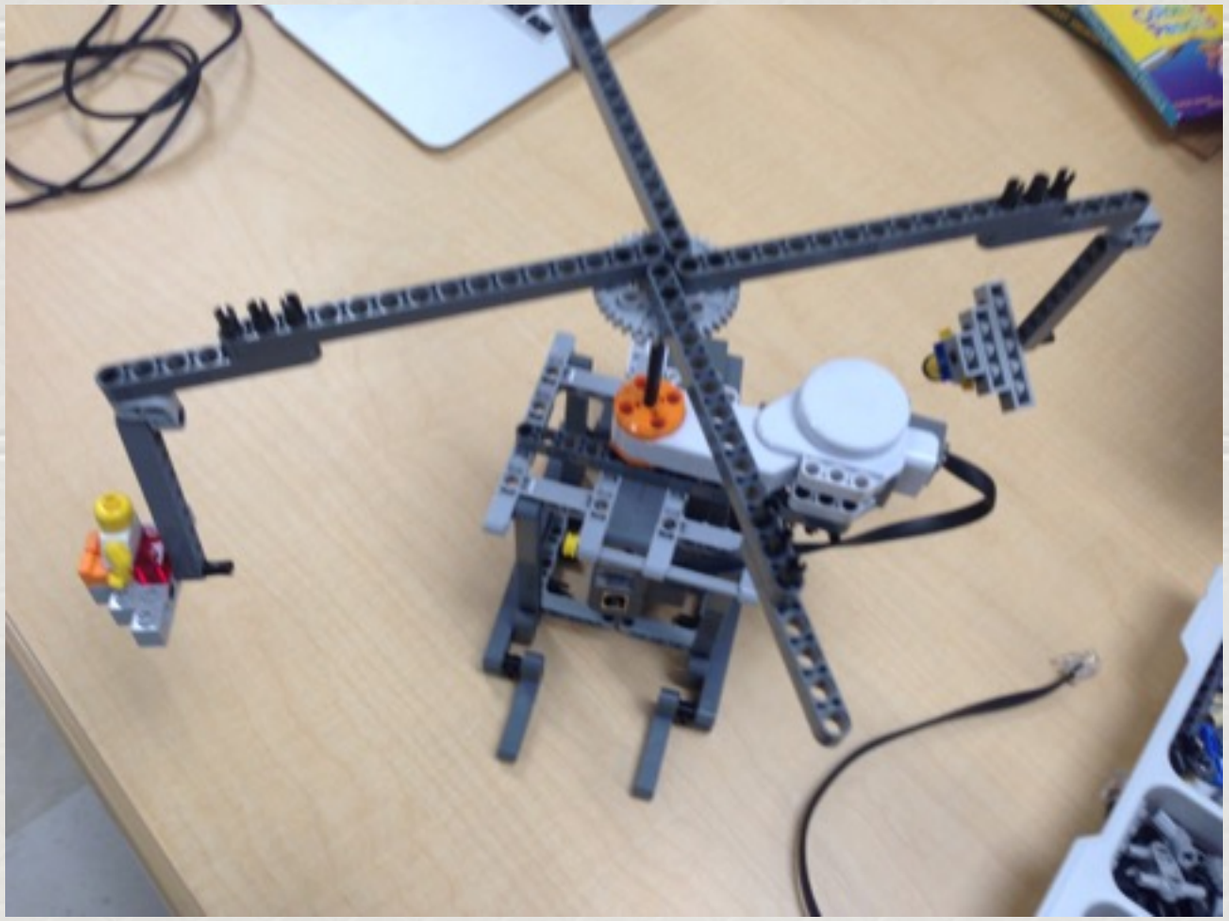
- *Rural PK-6 school*
- *6 typical boys and 6 typical girls*
- *Students started in K with robotics curriculum (Heffernan, 2013)*

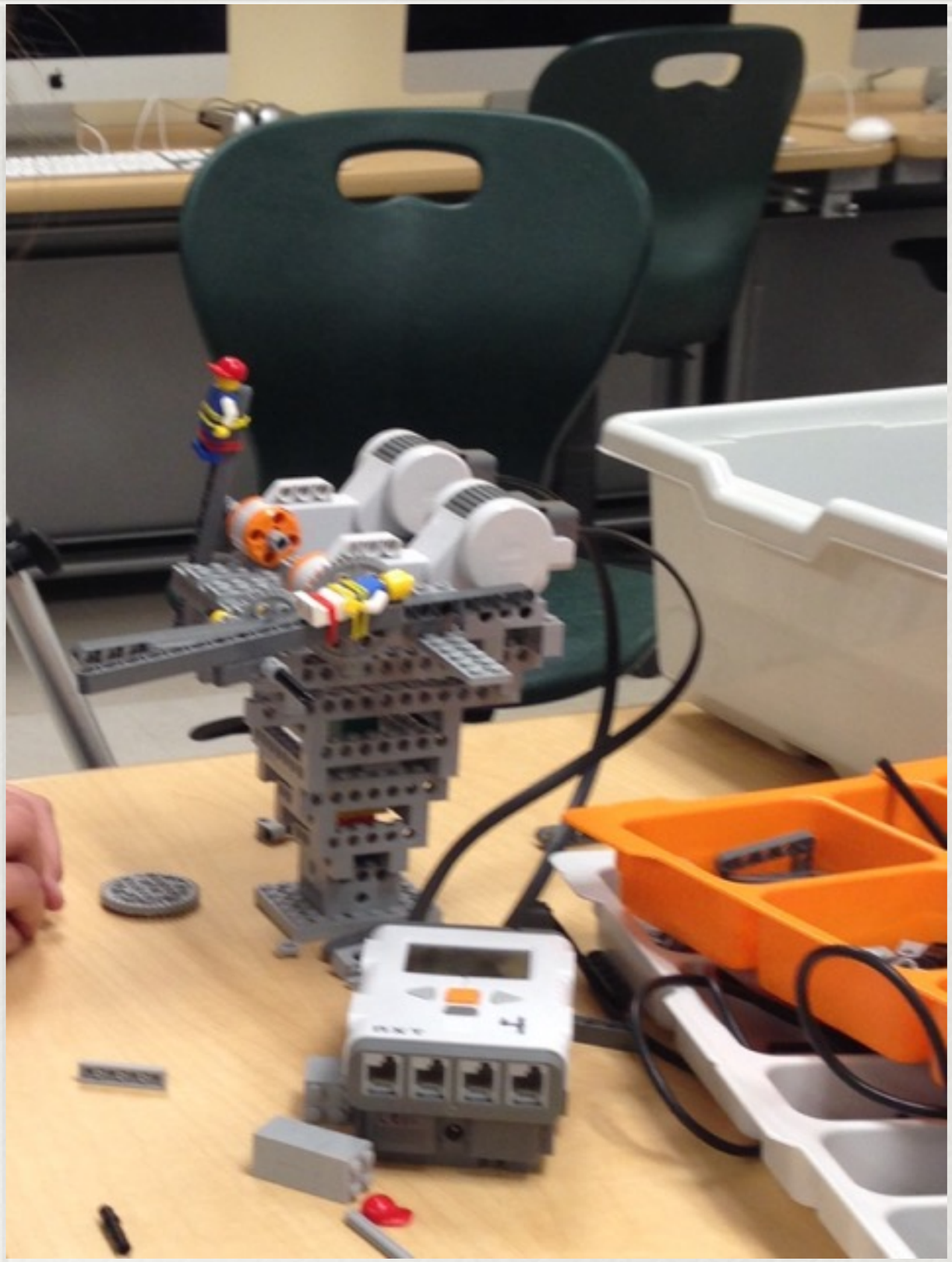
Data Collection

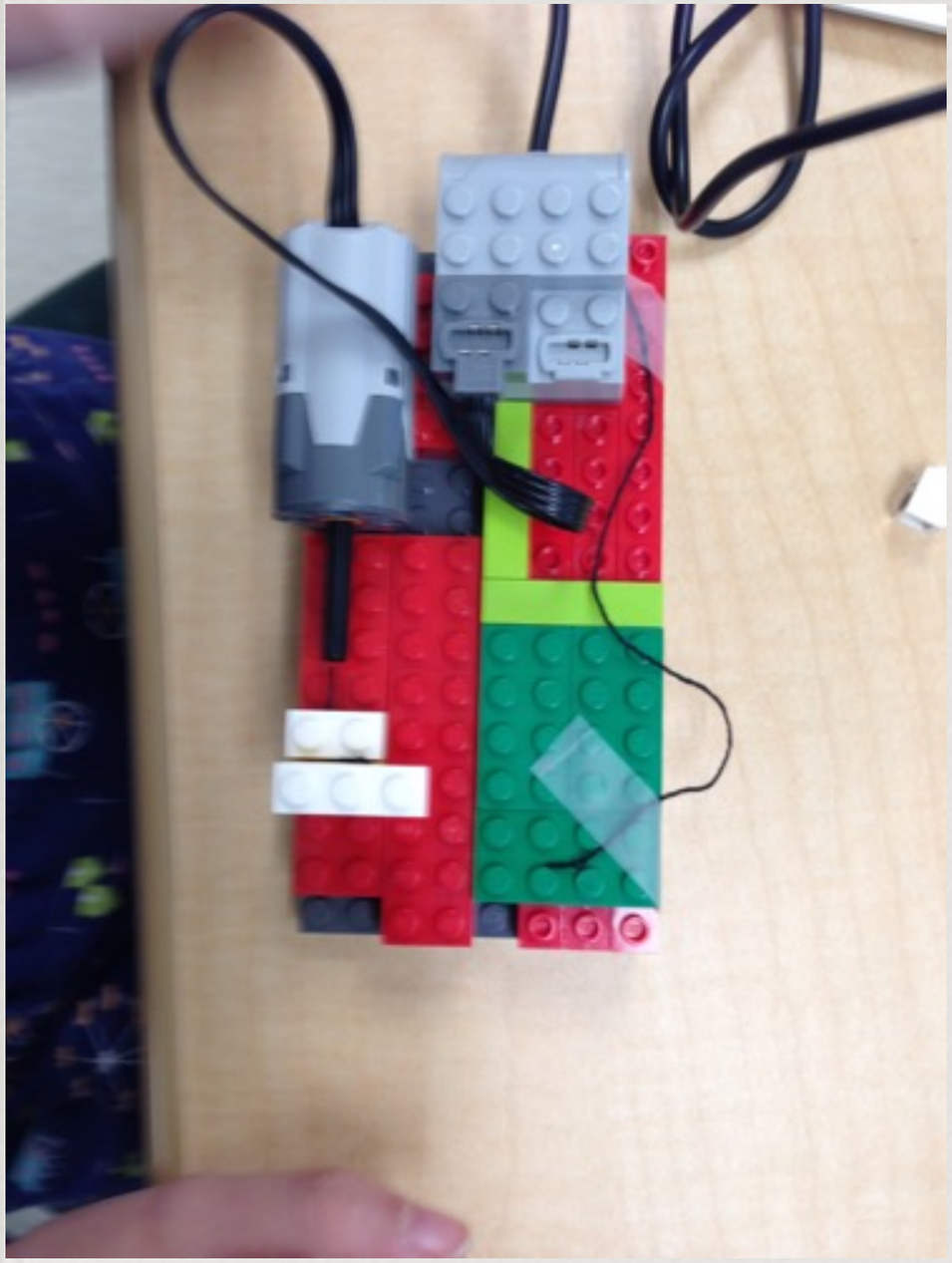
- *Warm up task (roof) - rubric*
- *Programs*
- *Photos of prototype*
- *Design data for each prototype - today*
- *Video tape of sessions - will yield EDP and CR data - future*

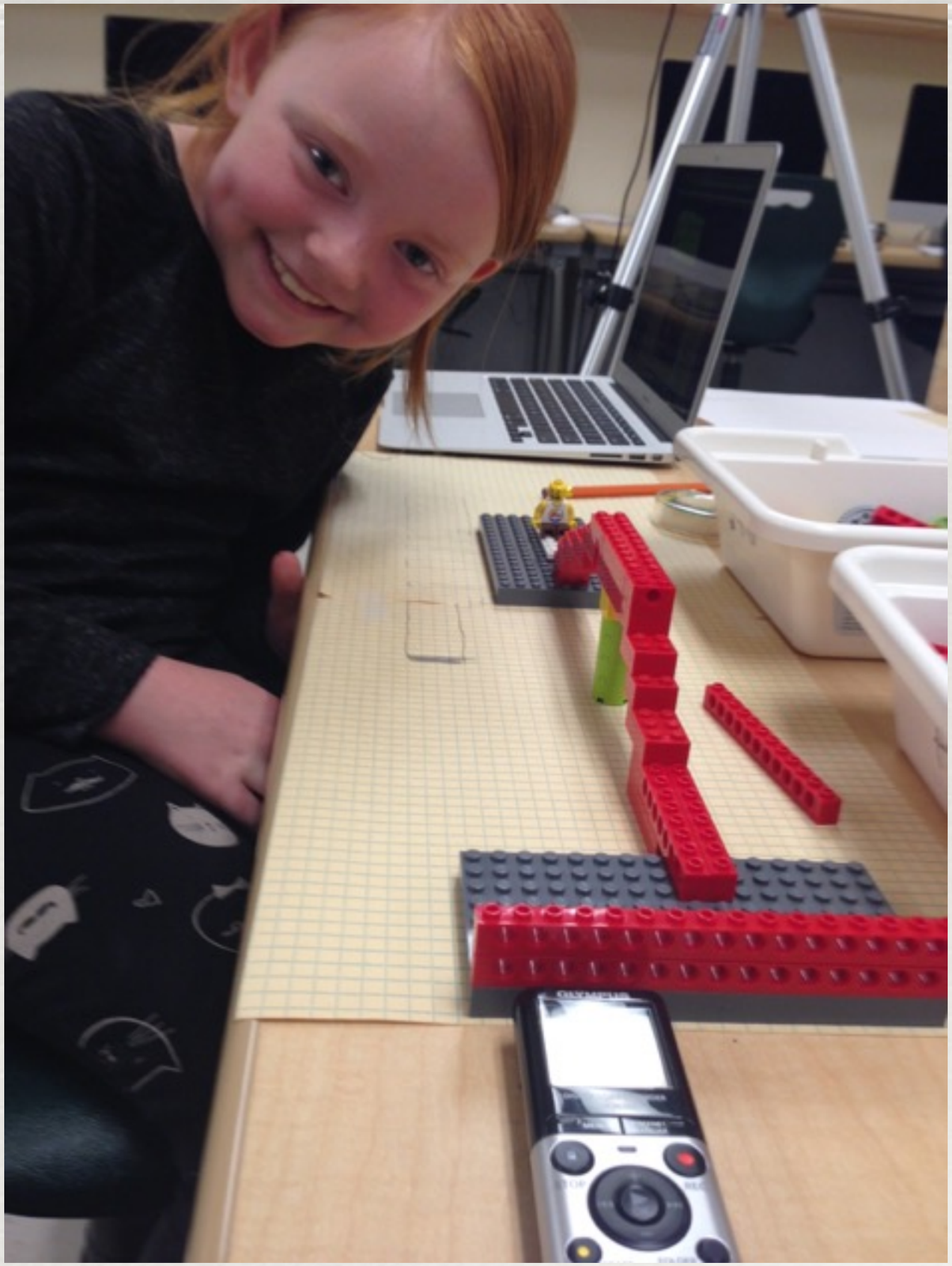
Data Collection Results

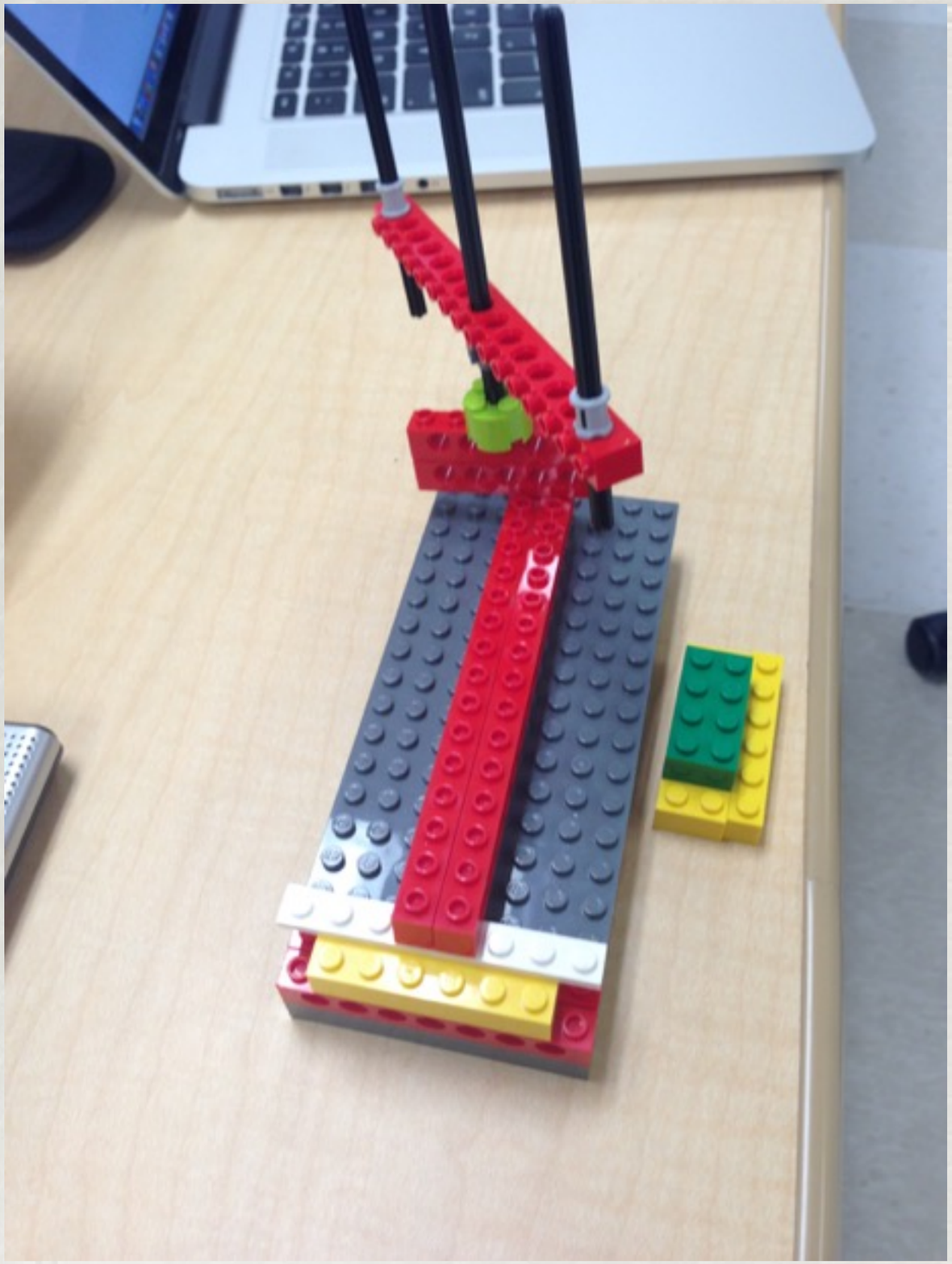
- *2 hours of warm task and 8.5 hours of main task*
- *some challenges with subjects and videotaping*
- *completed November-December*
- *multiple "track" issues with building and talking*
- *transcription, segmenting and time-stamping - pass 1 underway*

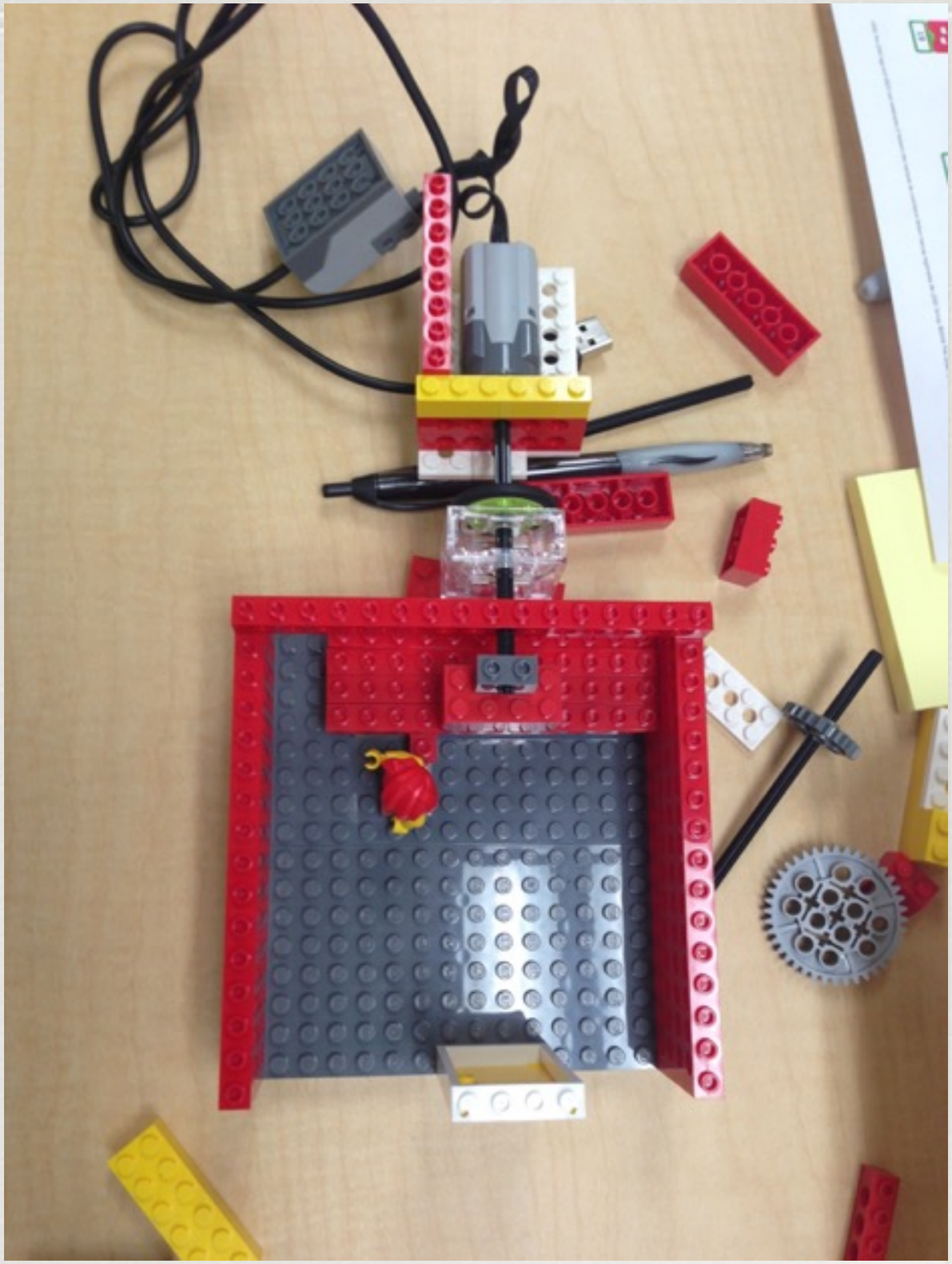


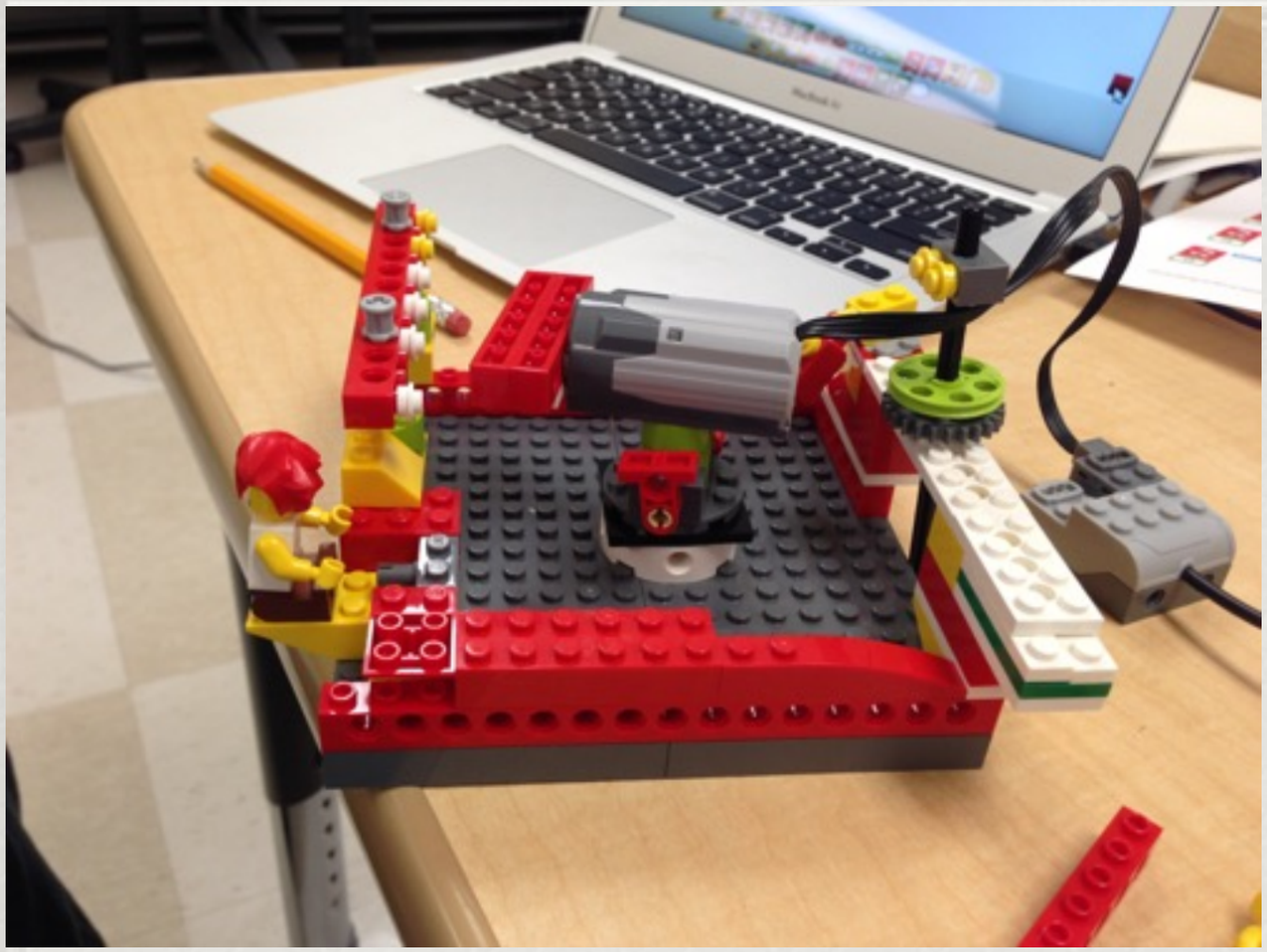


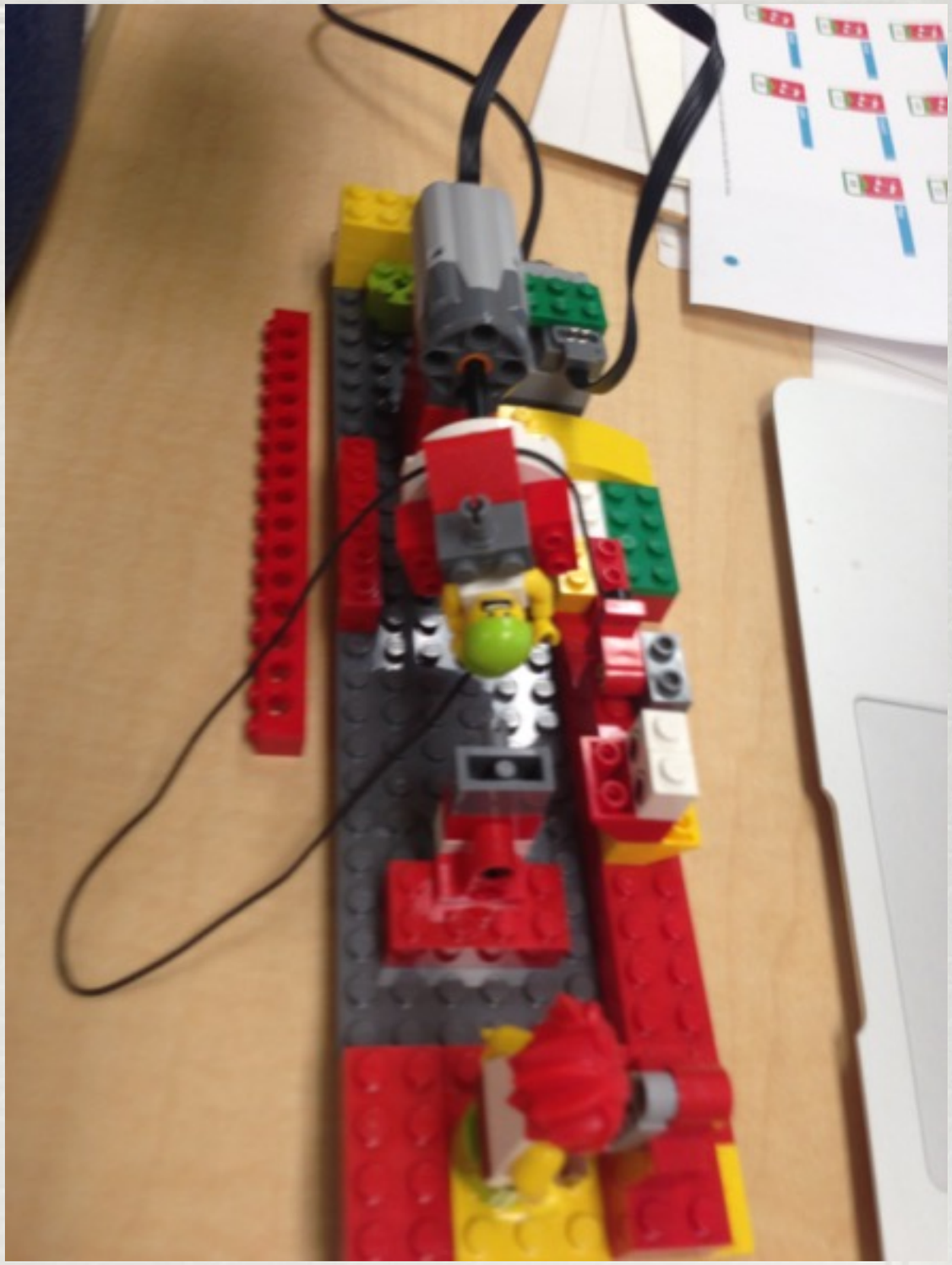


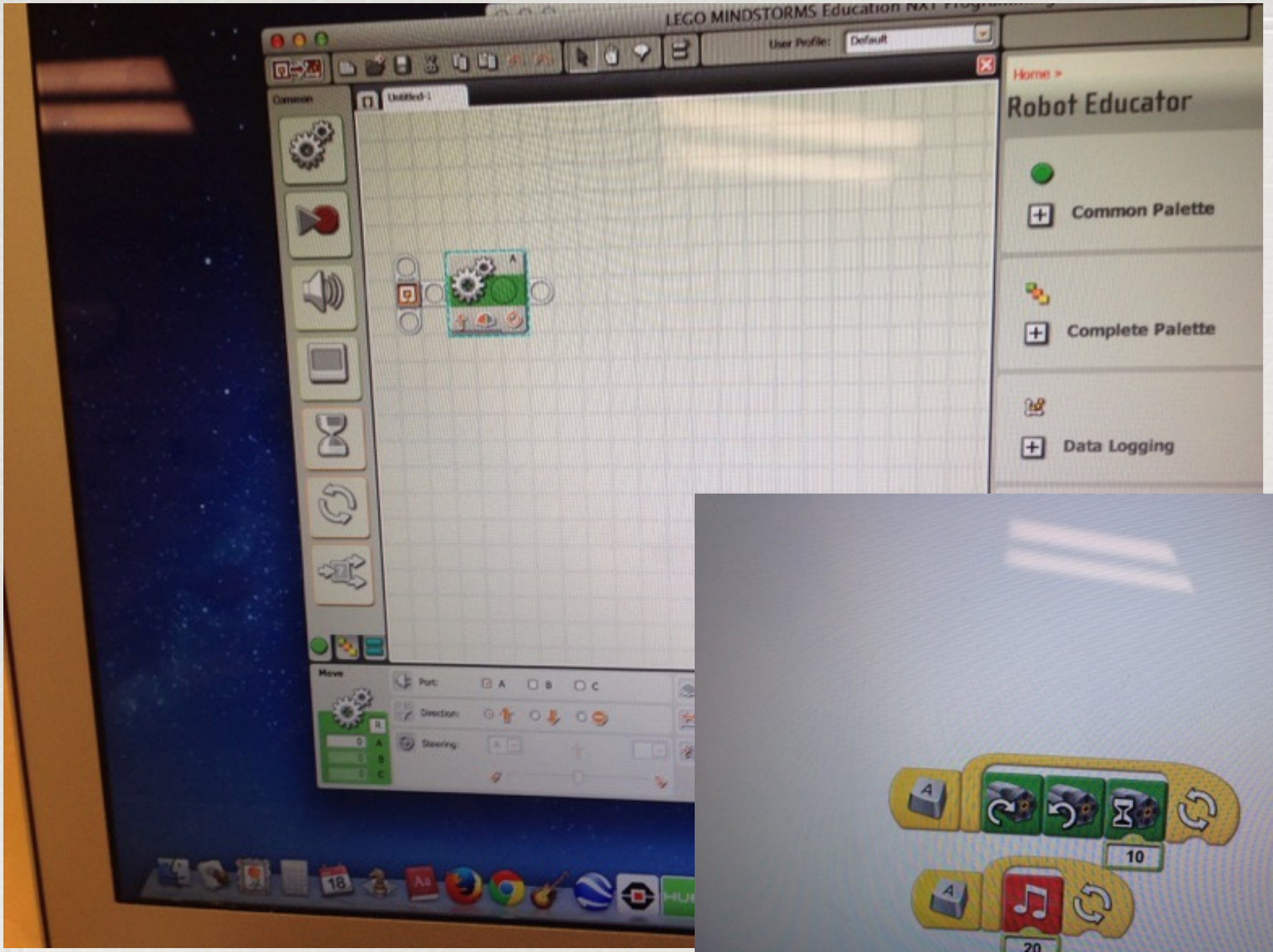











LEGO MINDSTORMS Education NXT
User Profile:
Default
Untitled-1
Home »
Robot Educator
Common Palette
Complete Palette
Data Logging
Move
Port:
A
B
C
Direction:
Steering:

A
10
A
20

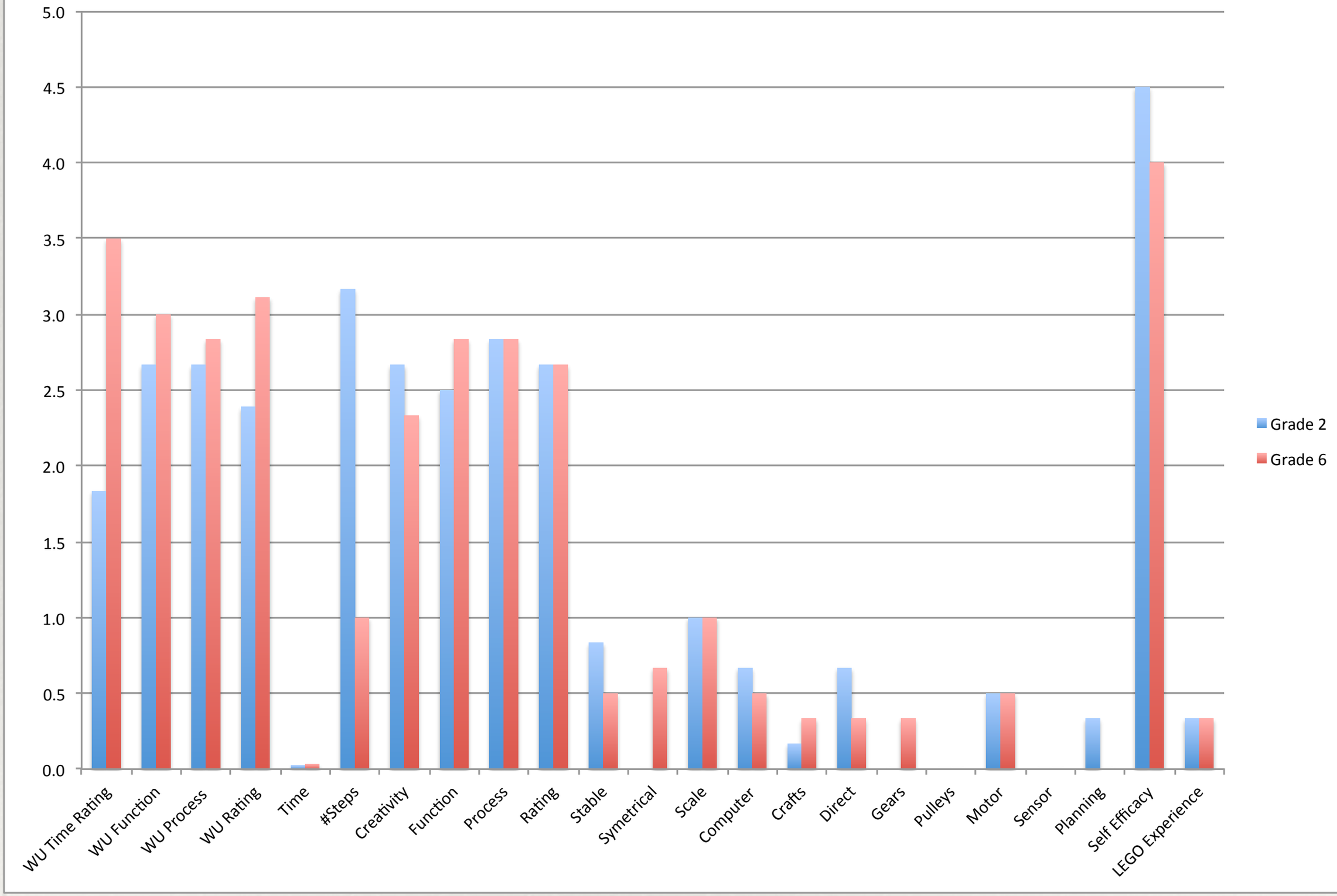
Design Data Analysis - Independent

- *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*

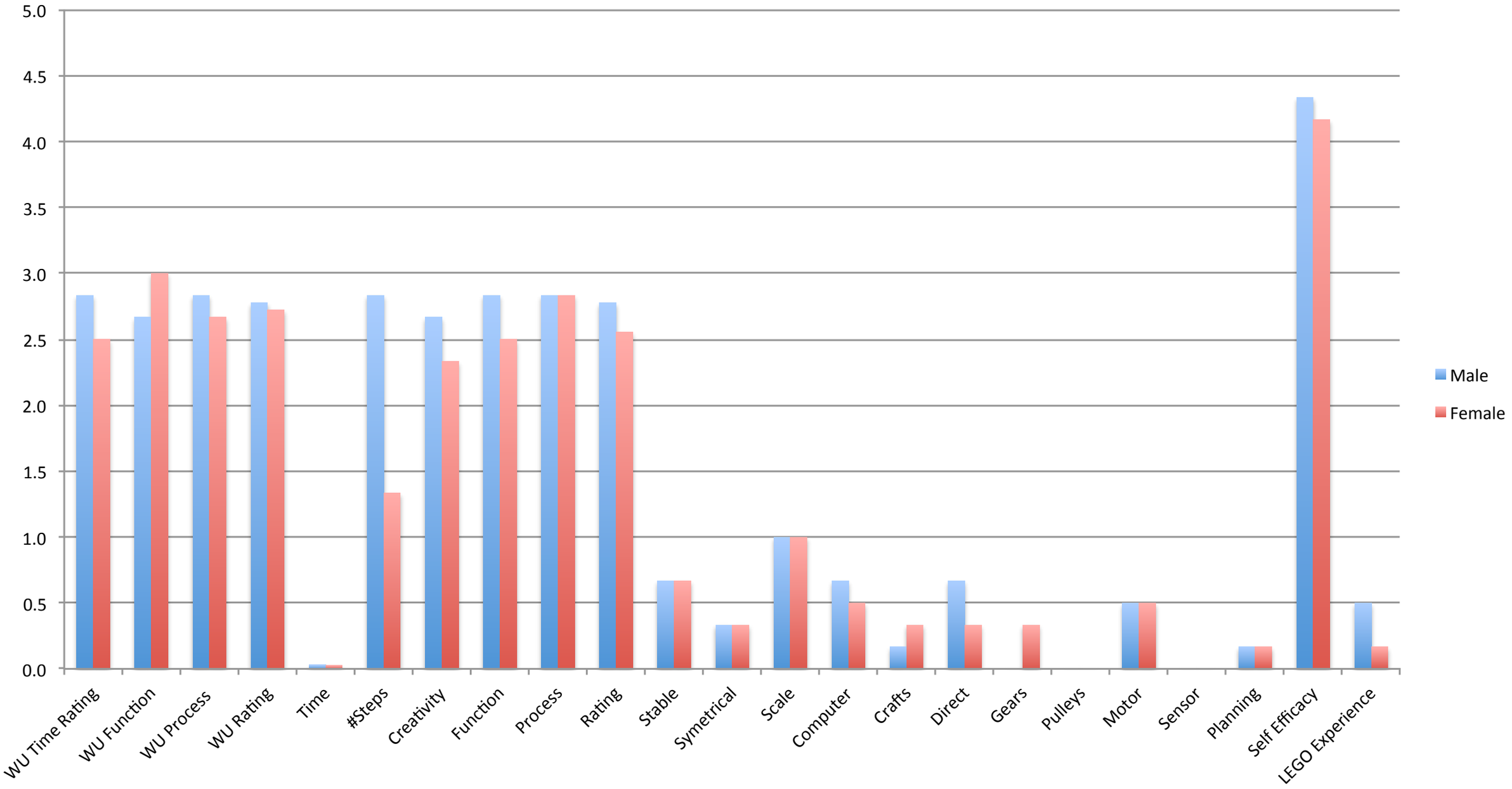
Design Data - Dependent

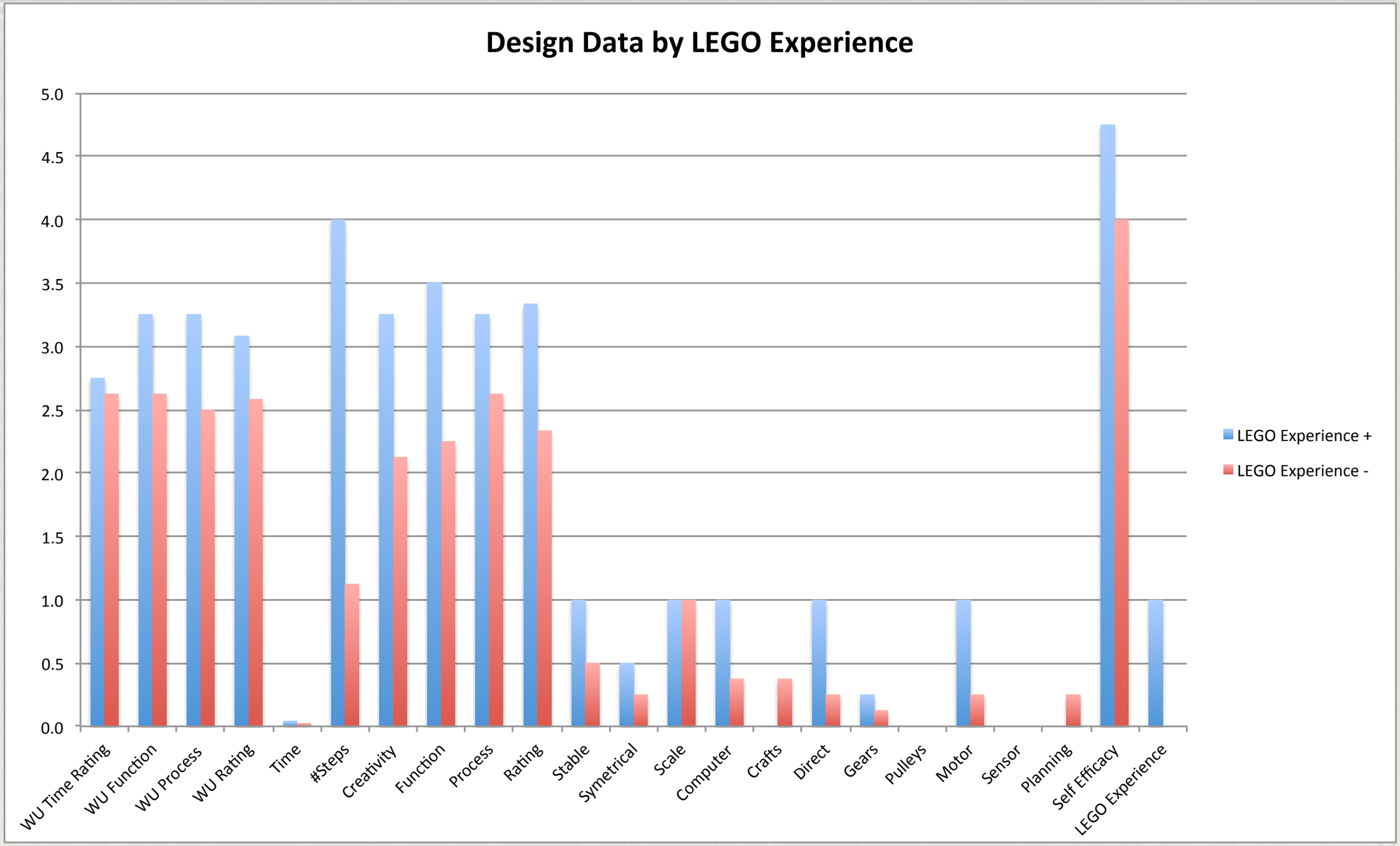
- *Gender*
- *Grade Level*
- *LEGO Experience*
- *Engineering Design Process*

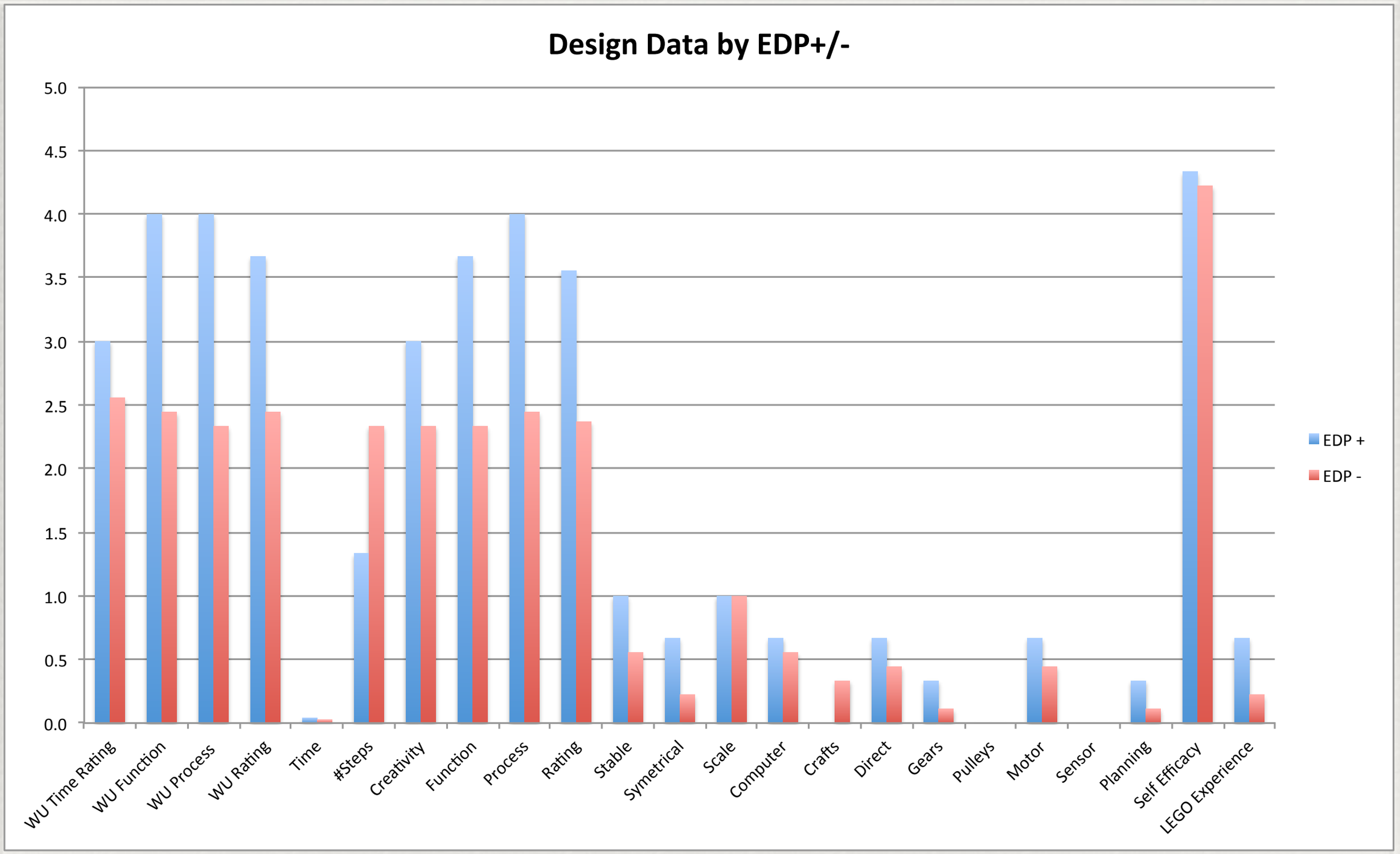
Design Data by Grade Level

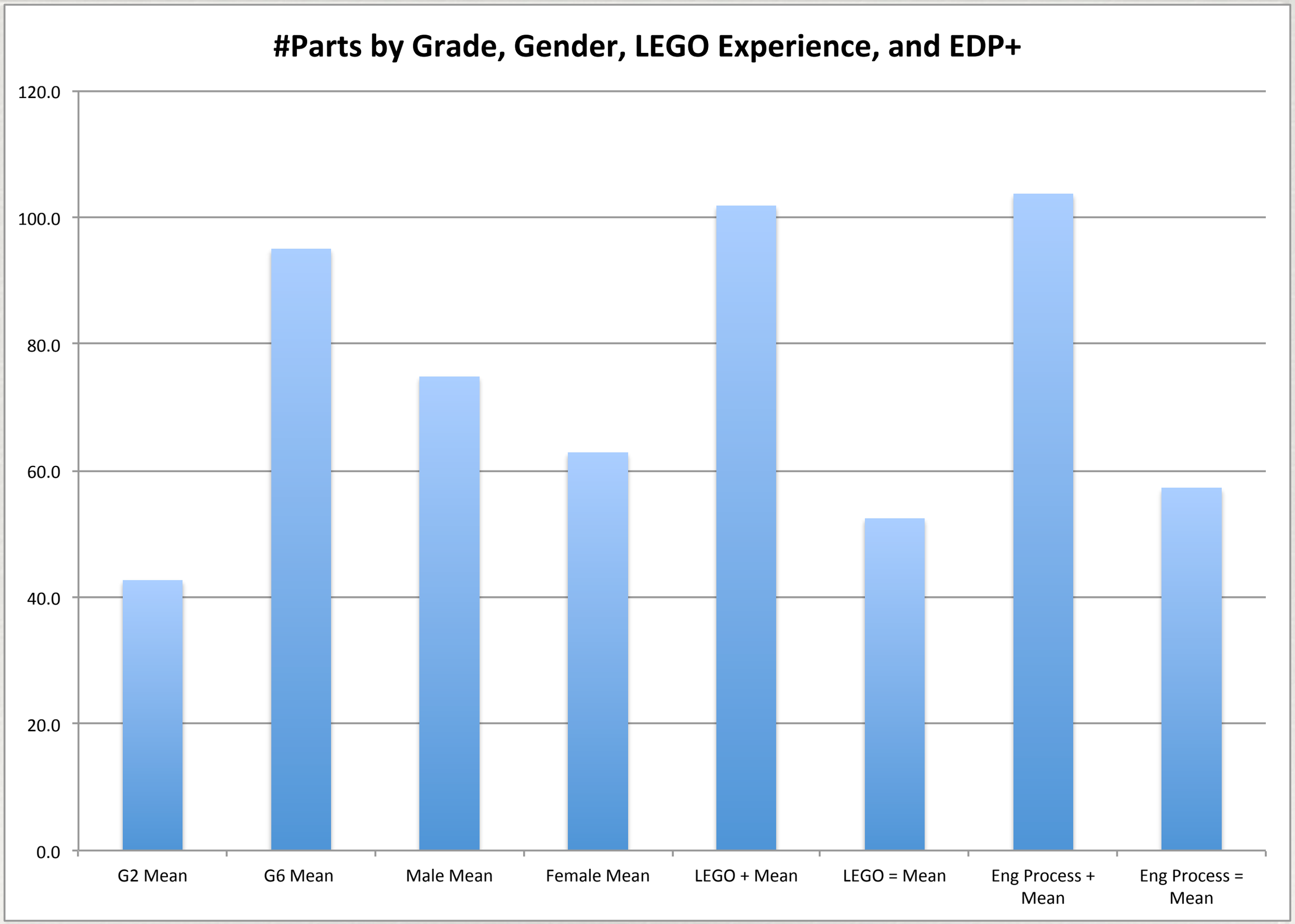


Design Data by Gender

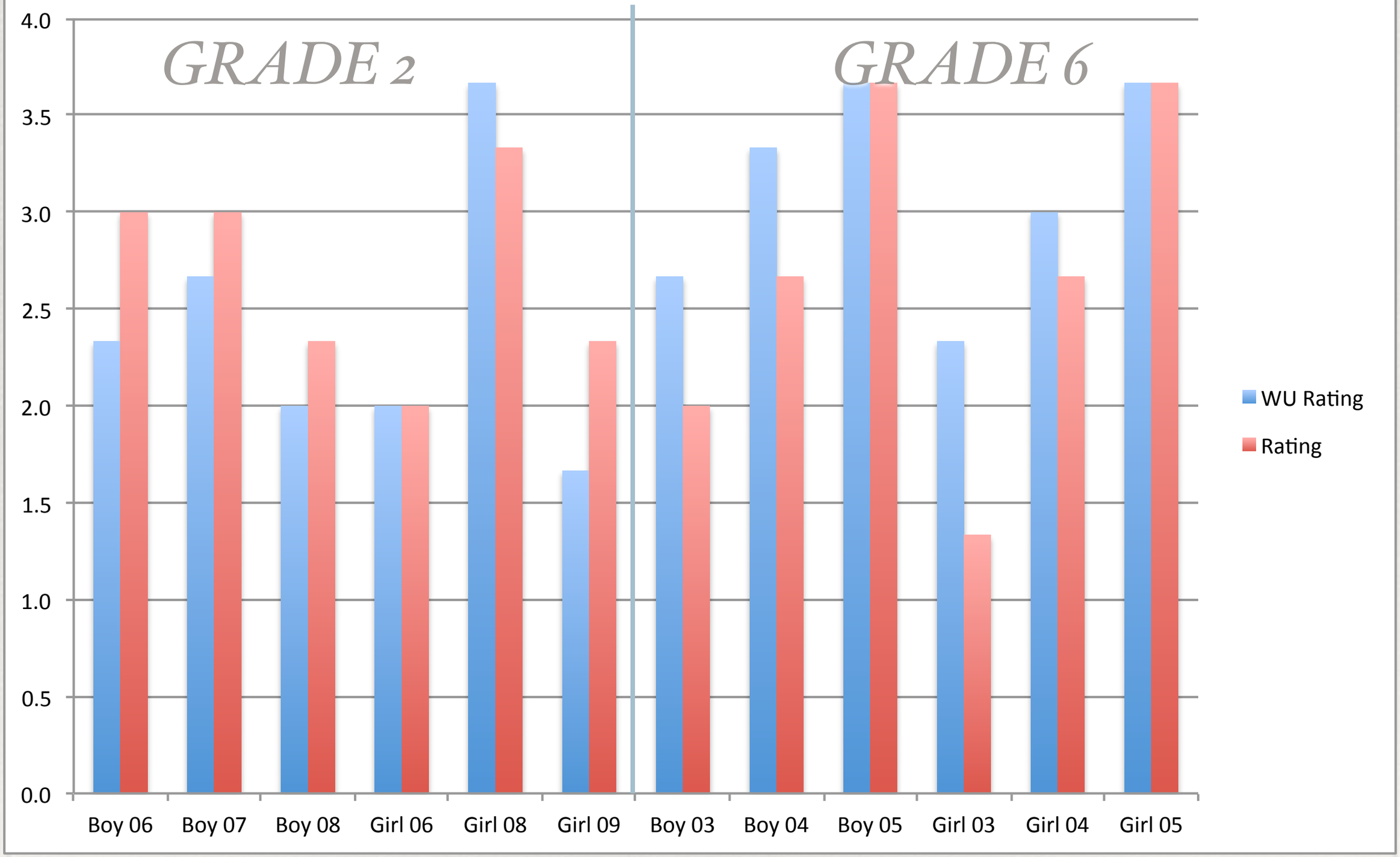



Design Data by LEGO Experience
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
WU Time Rating
WU Function
WU Process
WU Rating
Time
#Steps
Creativity
Function
Process
Rating
Stable
Symetrical
Scale
Computer
Crafts
Direct
Gears
Pulleys
Motor
Sensor
Planning
Self Efficacy
LEGO Experience
LEGO Experience +
LEGO Experience -

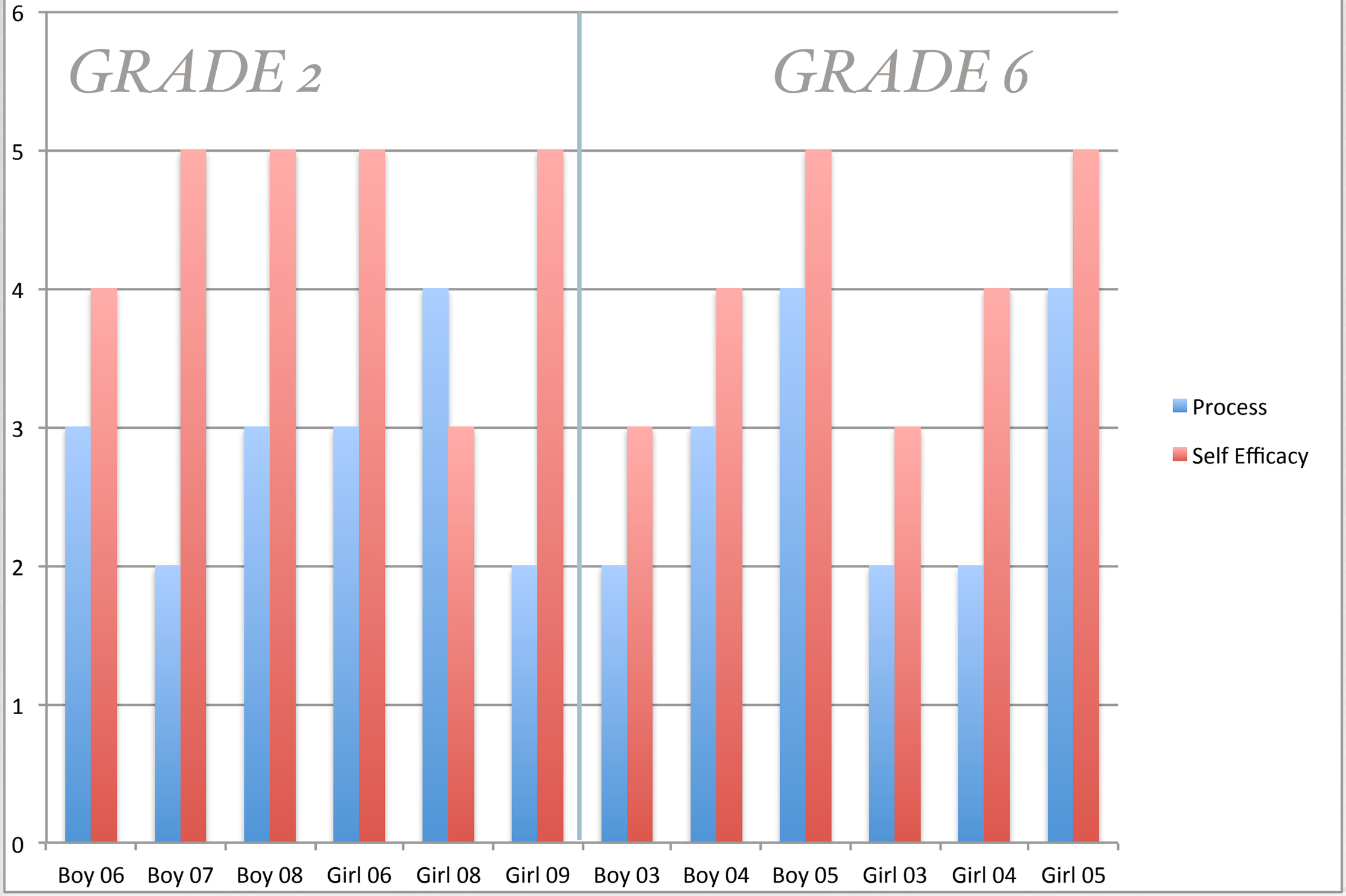

Design Data by EDP+/-
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
EDP +
EDP -
WU Time Rating
WU Function
WU Process
WU Rating
Time
#Steps
Creativity
Function
Process
Rating
Stable
Symetrical
Scale
Computer
Crafts
Direct
Gears
Pulleys
Motor
Sensor
Planning
Self Efficacy
LEGO Experience

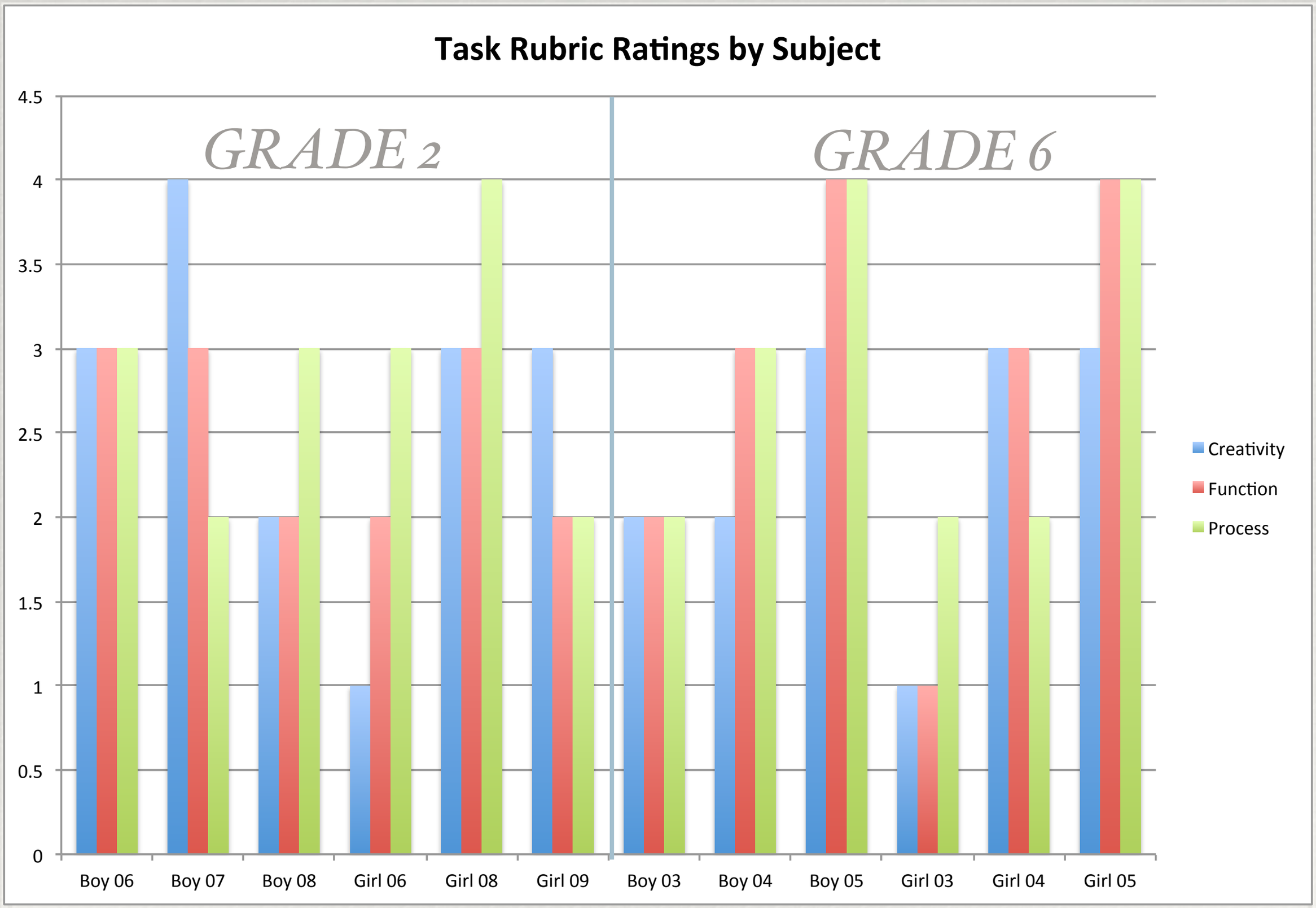

#Parts by Grade, Gender, LEGO Experience, and EDP+
120.0
100.0
80.0
60.0
40.0
20.0
0.0
G2 Mean
G6 Mean
Male Mean
Female Mean
LEGO + Mean
LEGO = Mean
Eng Process + Mean
Eng Process = Mean

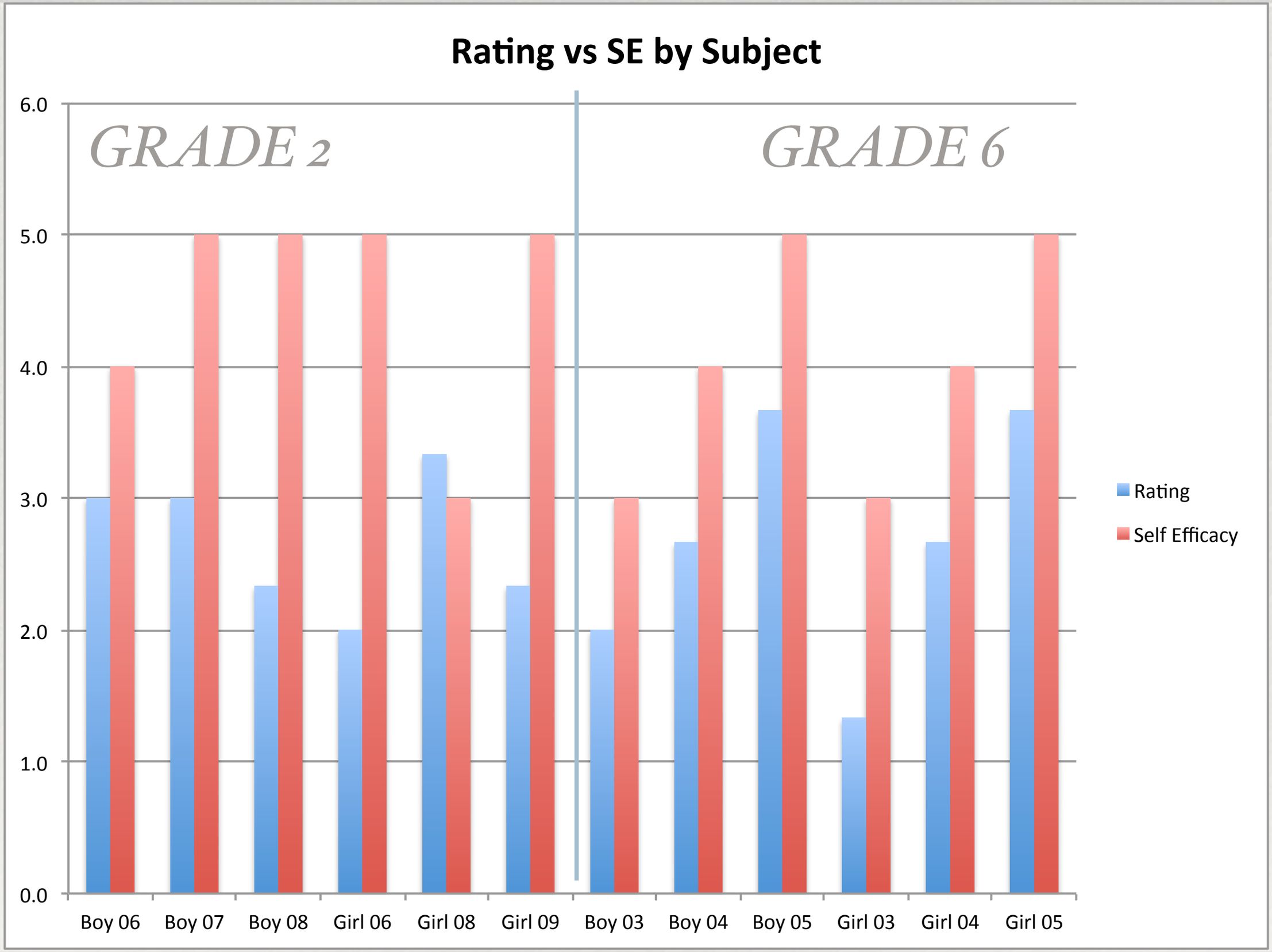
Warm Up and Task Rating by Subject



EDP Vs SE by Subject

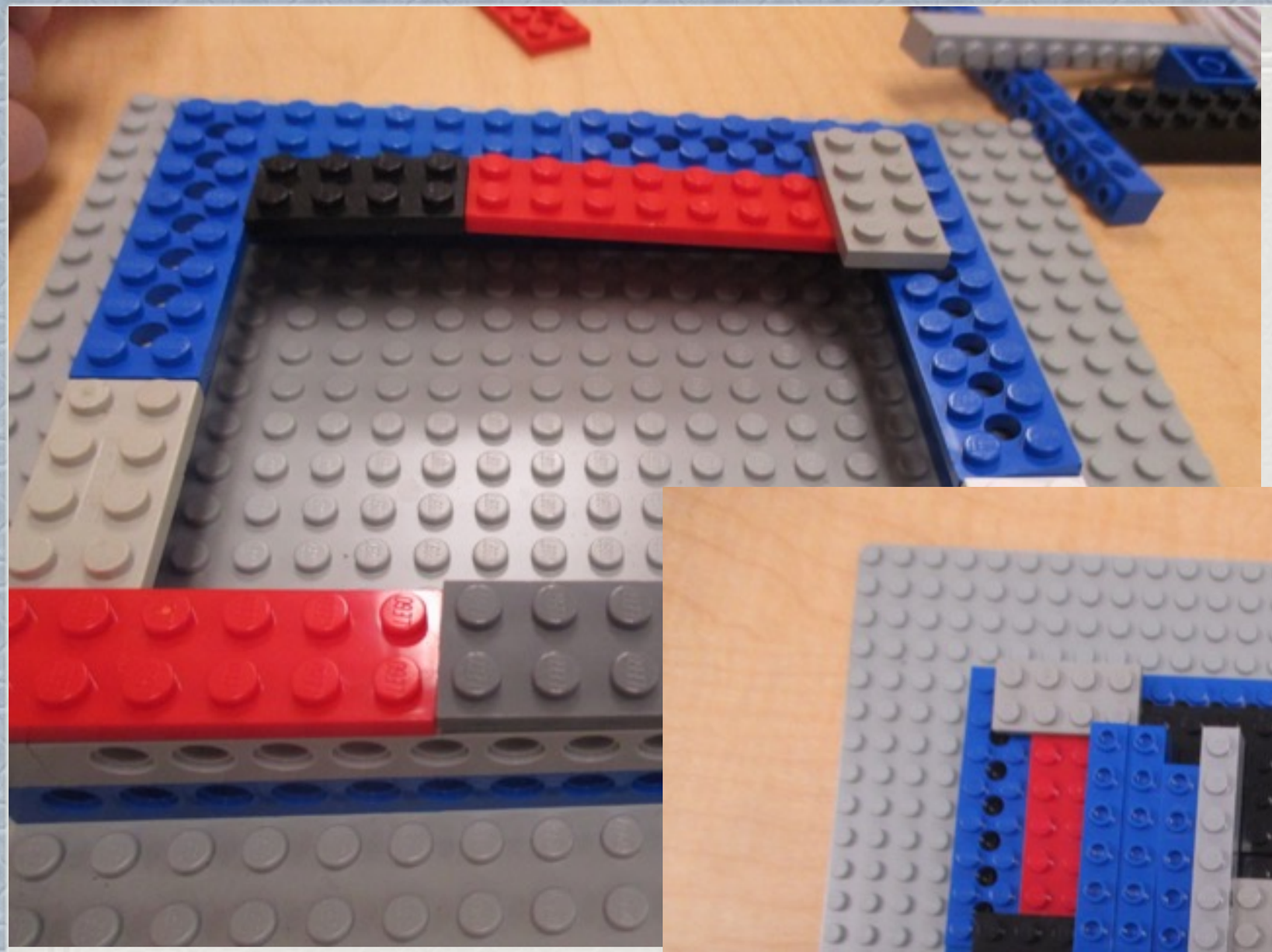


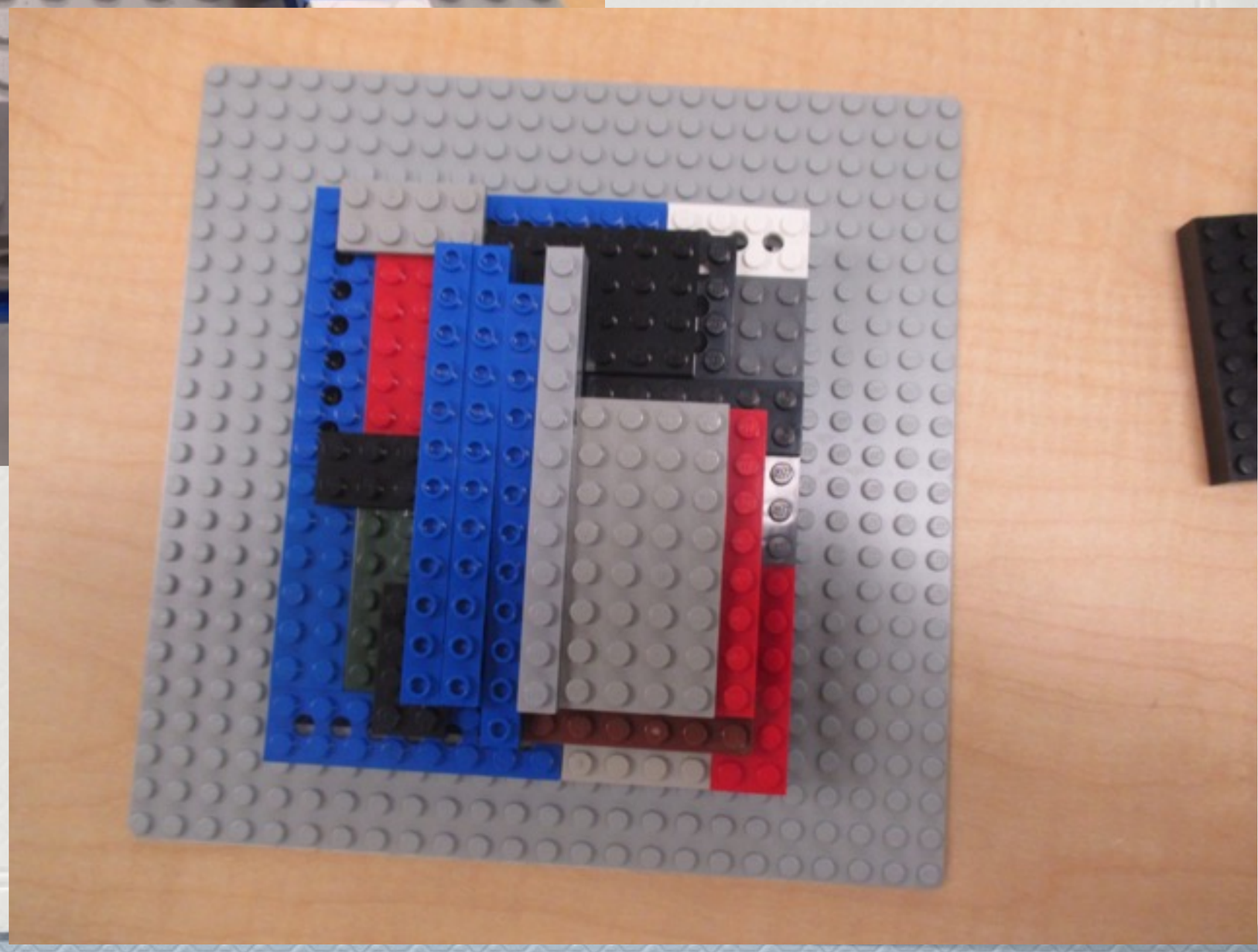

Task Rubric Ratings by Subject
GRADE 2
GRADE 6
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Boy 06
Boy 07
Boy 08
Girl 06
Girl 08
Girl 09
Boy 03
Boy 04
Boy 05
Girl 03
Girl 04
Girl 05
Creativity
Function
Process


Rating vs SE by Subject
GRADE 2
GRADE 6
6.0
5.0
4.0
3.0
2.0
1.0
0.0
Boy 06
Boy 07
Boy 08
Girl 06
Girl 08
Girl 09
Boy 03
Boy 04
Boy 05
Girl 03
Girl 04
Girl 05
Rating
Self Efficacy

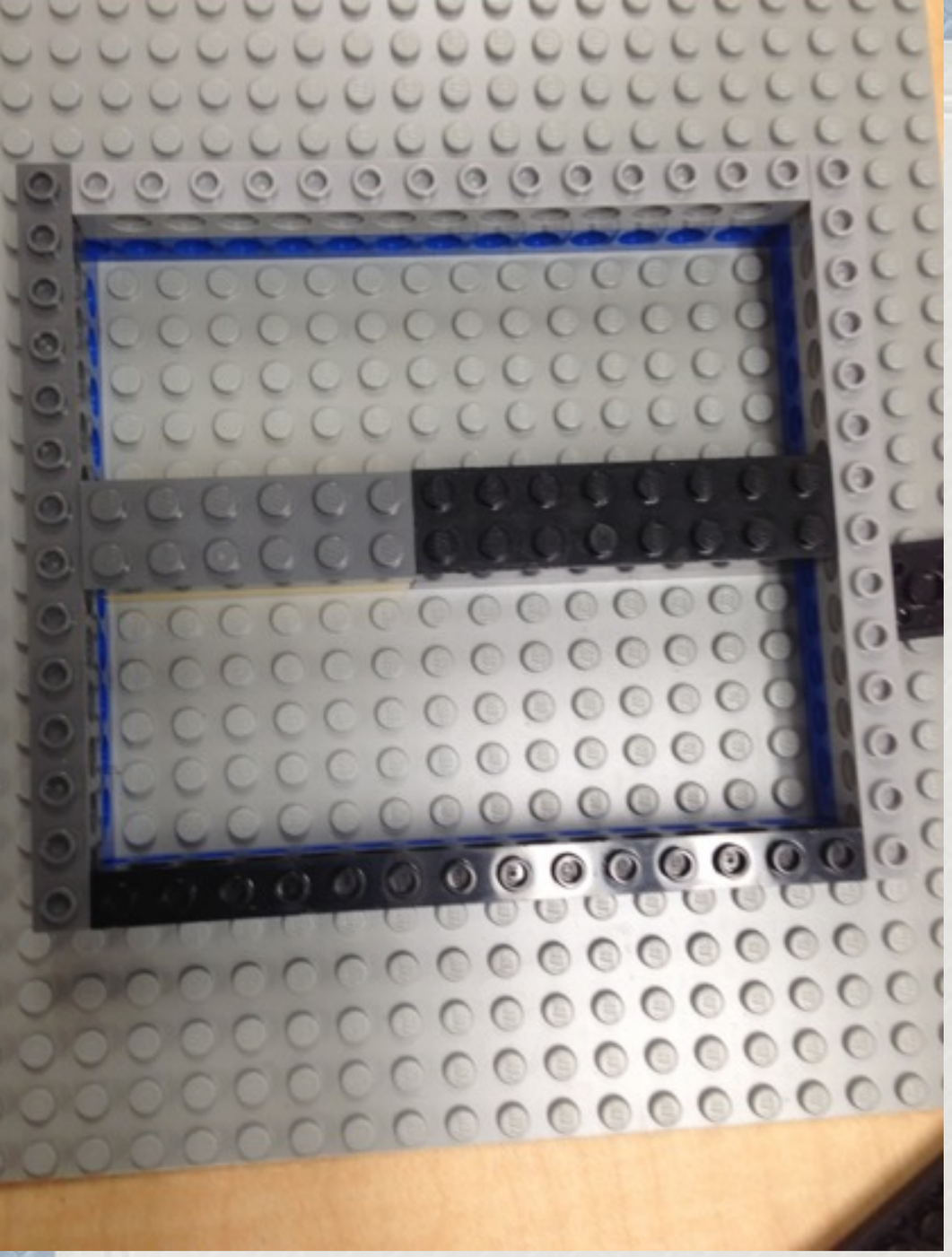
Big Ideas - Warm Up Task

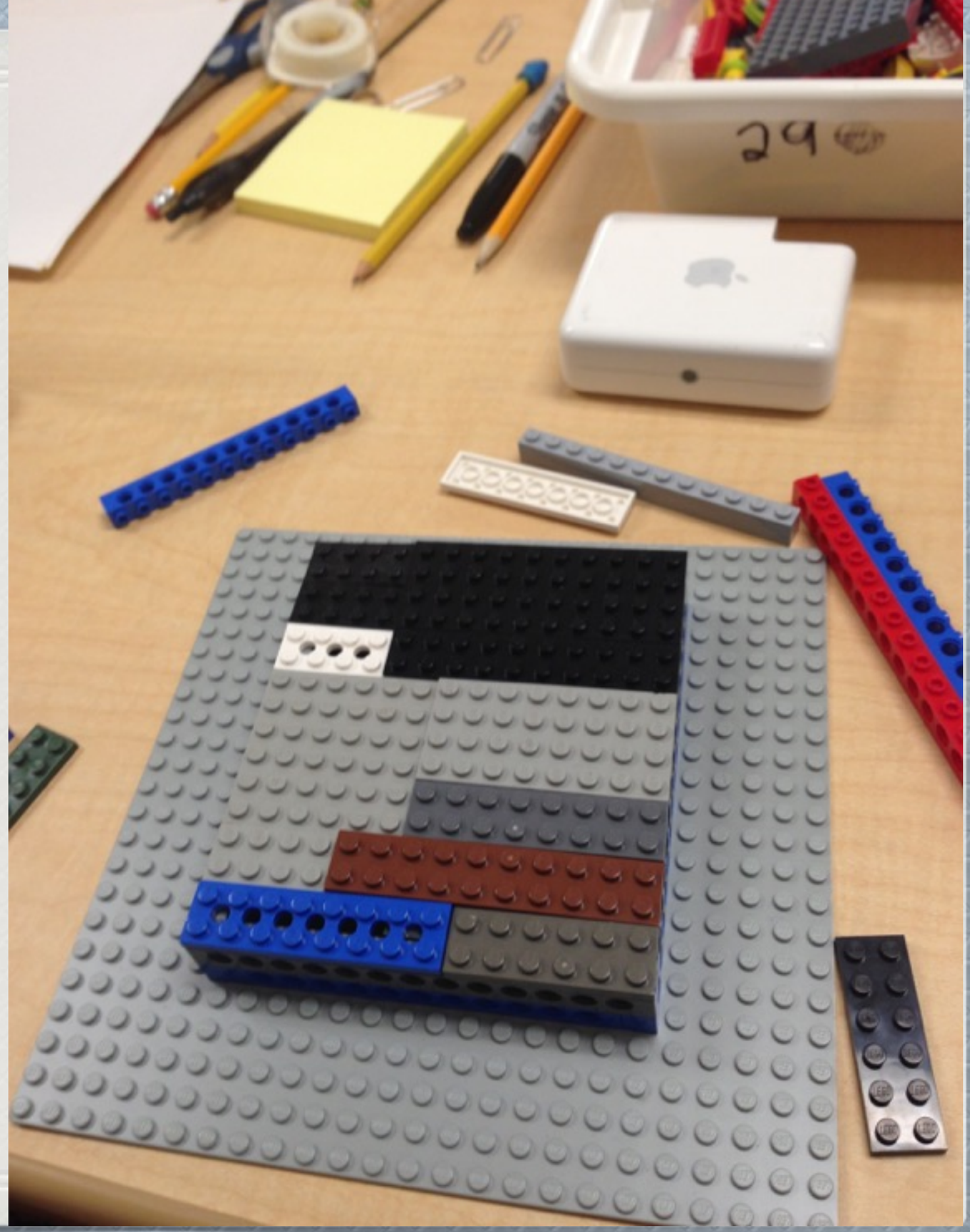
- *Correlated with main task*
- *Some found it hard to attend to both constraints*
- *Structural knowledge of structures important*



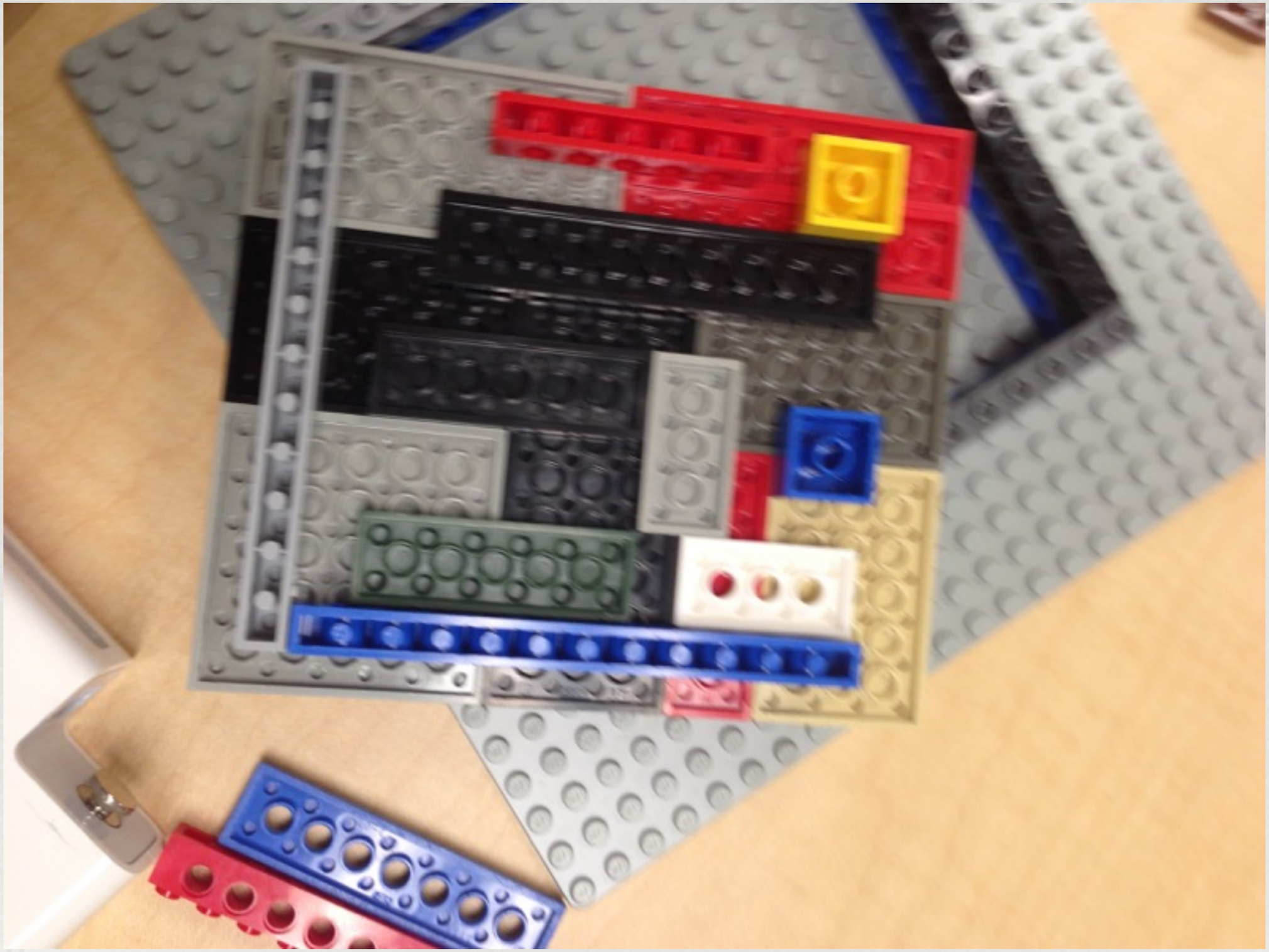


G2 Patchwork



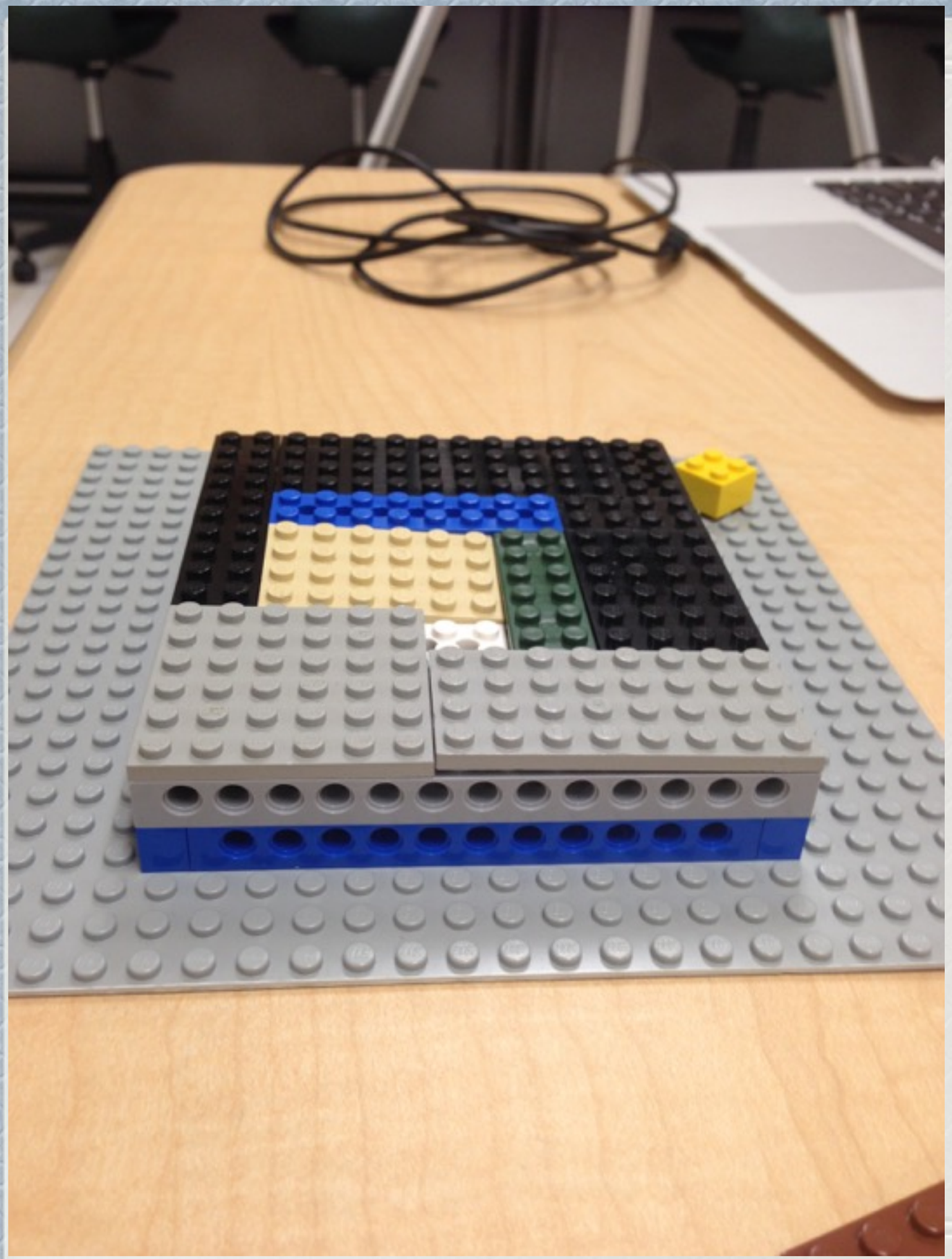


G2 Interior Walls



G6 Removable Roof

G6 Interior Walls



G6 Underneath
Composite Pieces

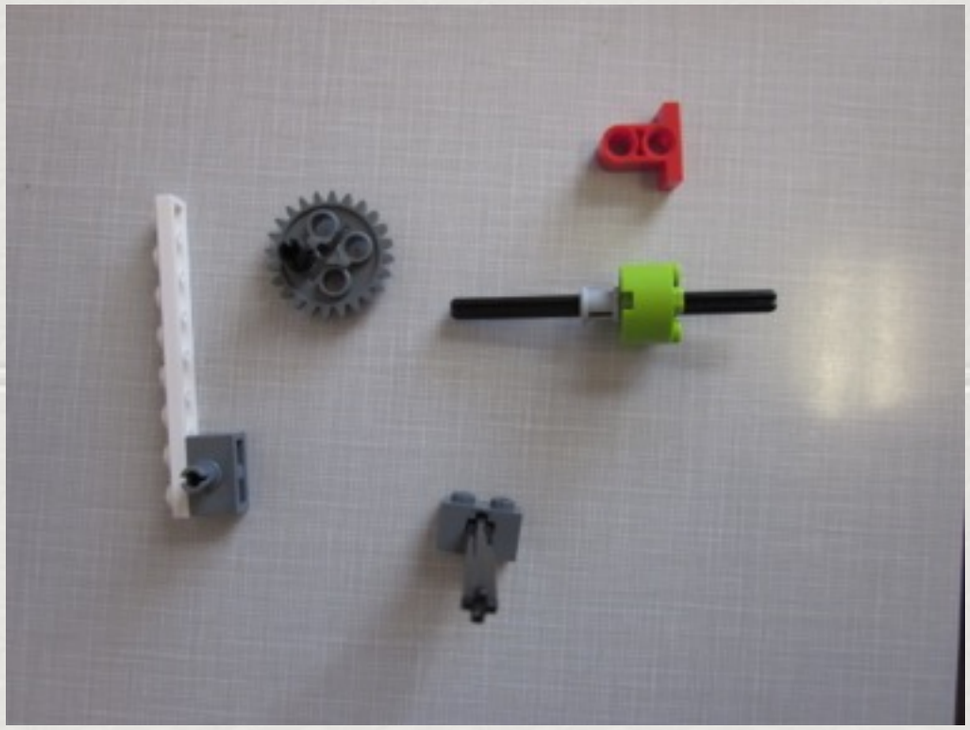
Big Ideas - Main Task

- *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*

Big Ideas - EDP

- *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)*

Transcript Example

[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.

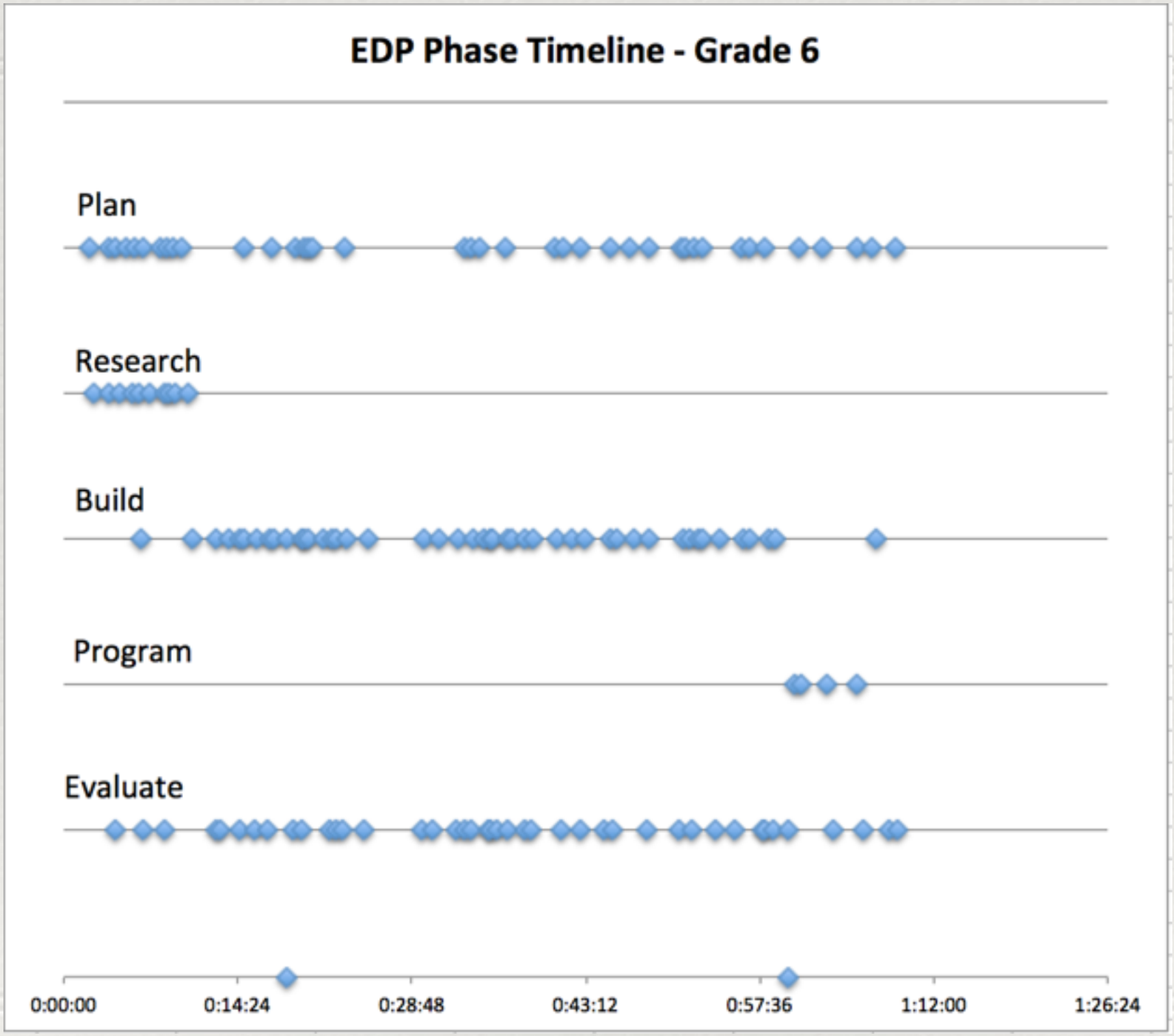
Actually, I think I might have it work like this, holding this up so this doesn't move back and forth.

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

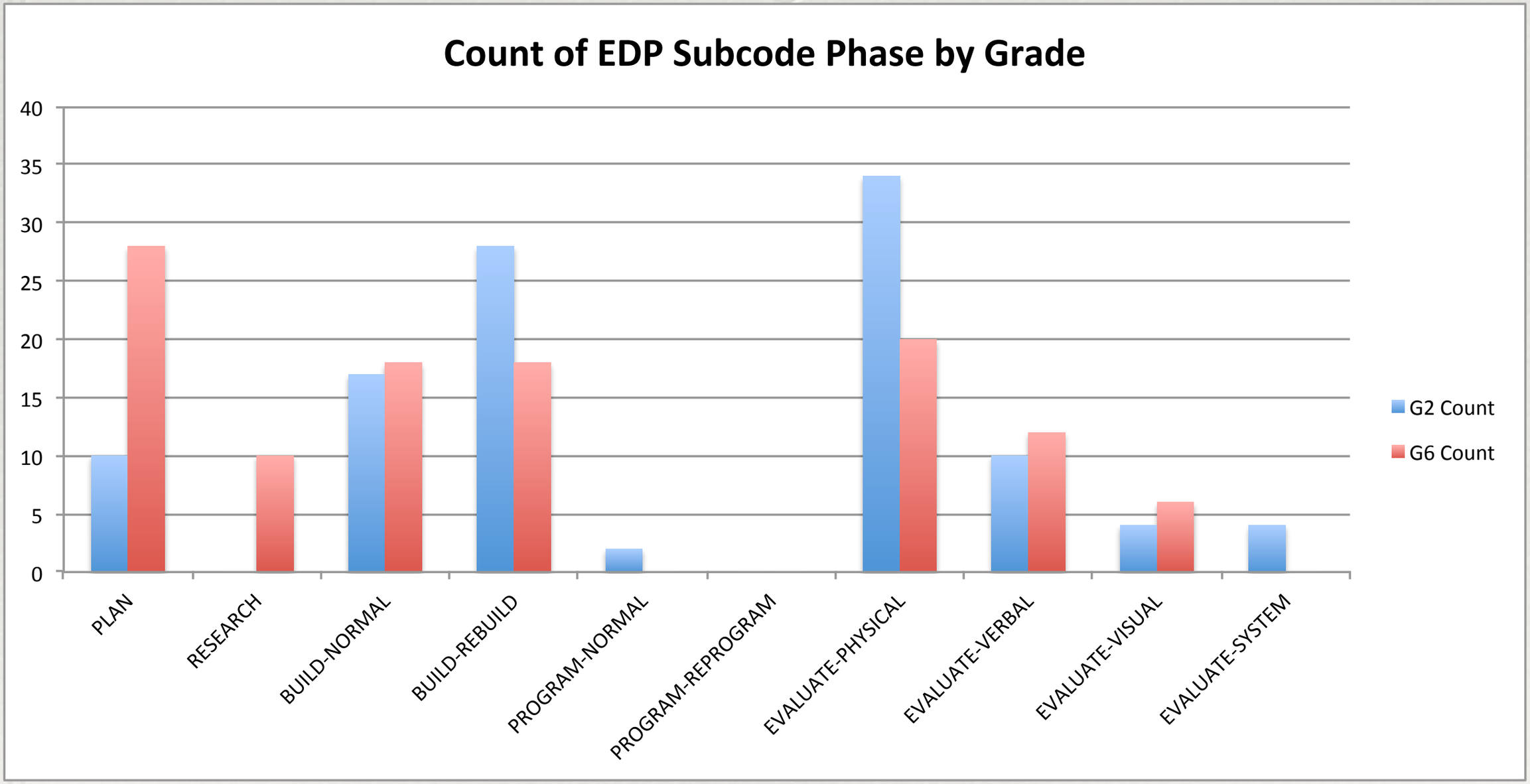
[00:05:01] [PLAN] {no_activity} Boy 05: I'm going to add these so they can connect.

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

EDP Timeline (Pilot)



EDP Frequency Chart (Pilot)



Non-EDP Codes

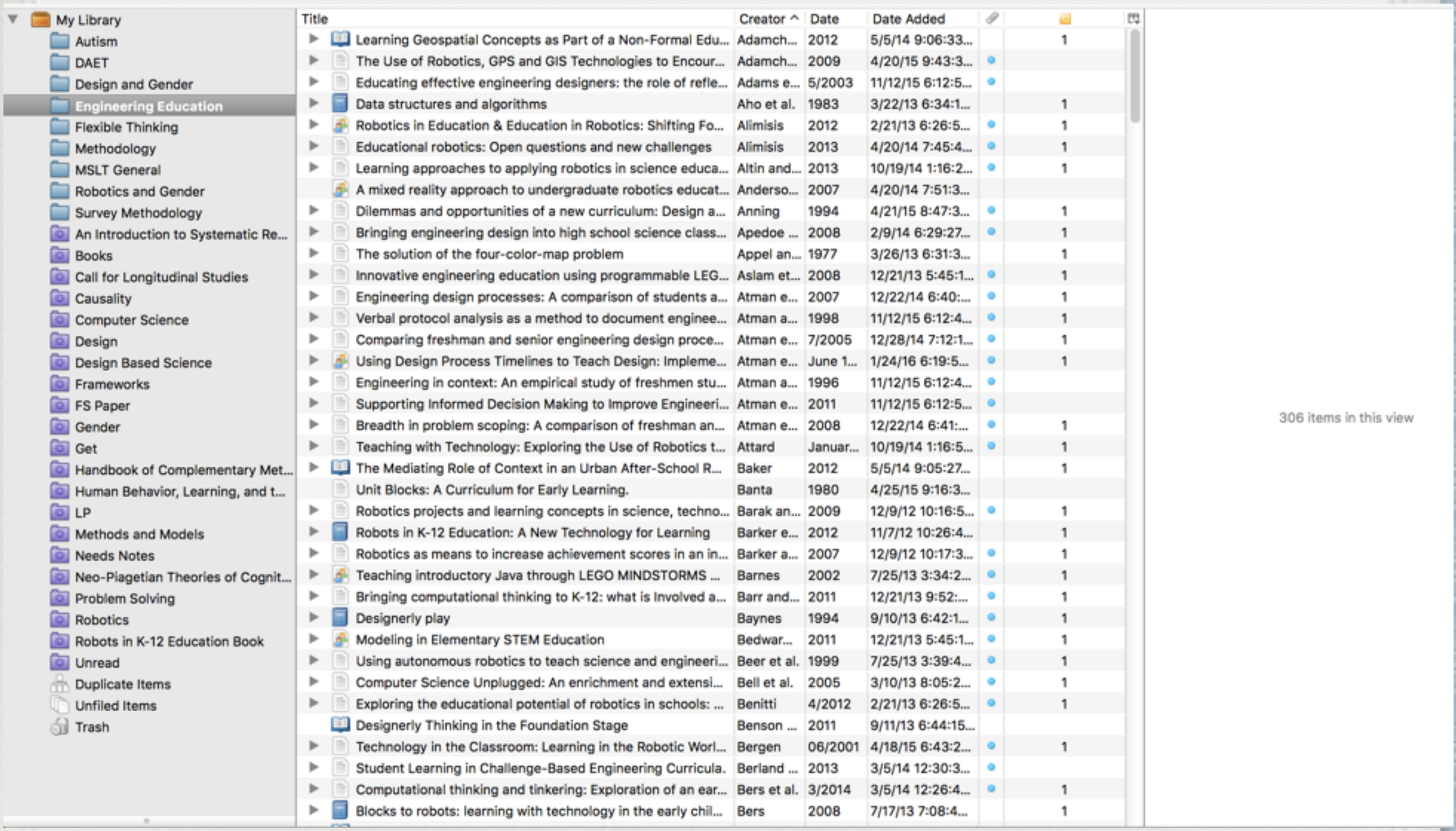
- *These will be tabulated and graphed by frequency and dependent variables*

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*


My Library
Autism
DAET
Design and Gender
Engineering Education
Flexible Thinking
Methodology
MSLT General
Robotics and Gender
Survey Methodology
An Introduction to Systematic Re...
Books
Call for Longitudinal Studies
Causality
Computer Science
Design
Design Based Science
Frameworks
FS Paper
Gender
Get
Handbook of Complementary Met...
Human Behavior, Learning, and t...
LP
Methods and Models
Needs Notes
Neo-Piagetian Theories of Cognit...
Problem Solving
Robotics
Robots in K-12 Education Book
Unread
Duplicate Items
Unfiled Items
Trash
Title
Creator
Date
Date Added
Learning Geospatial Concepts as Part of a Non-Formal Edu... Adamch... 2012 5/5/14 9:06:33... 1
The Use of Robotics, GPS and GIS Technologies to Encour... Adamch... 2009 4/20/15 9:43:3...
Educating effective engineering designers: the role of refle... Adams e... 5/2003 11/12/15 6:12:5...
Data structures and algorithms Aho et al. 1983 3/22/13 6:34:1... 1
Robotics in Education & Education in Robotics: Shifting Fo... Alimisis 2012 2/21/13 6:26:5... 1
Educational robotics: Open questions and new challenges Alimisis 2013 4/20/14 7:45:4... 1
Learning approaches to applying robotics in science educa... Altin and... 2013 10/19/14 1:16:2... 1
A mixed reality approach to undergraduate robotics educat... Anderso... 2007 4/20/14 7:51:3...
Dilemmas and opportunities of a new curriculum: Design a... Anning 1994 4/21/15 8:47:3... 1
Bringing engineering design into high school science class... Apedoe ... 2008 2/9/14 6:29:27... 1
The solution of the four-color-map problem Appel an... 1977 3/26/13 6:31:3... 1
Innovative engineering education using programmable LEG... Aslam et... 2008 12/21/13 5:45:1... 1
Engineering design processes: A comparison of students a... Atman e... 2007 12/22/14 6:40:... 1
Verbal protocol analysis as a method to document enginee... Atman a... 1998 11/12/15 6:12:4... 1
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Using Design Process Timelines to Teach Design: Impleme... Atman e... June 1... 1/24/16 6:19:5... 1
Engineering in context: An empirical study of freshmen stu... Atman a... 1996 11/12/15 6:12:4...
Supporting Informed Decision Making to Improve Engineeri... Atman e... 2011 11/12/15 6:12:5...
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Teaching with Technology: Exploring the Use of Robotics t... Attard Januar... 10/19/14 1:16:5... 1
The Mediating Role of Context in an Urban After-School R... Baker 2012 5/5/14 9:05:27... 1
Unit Blocks: A Curriculum for Early Learning. Banta 1980 4/25/15 9:16:3...
Robotics projects and learning concepts in science, techno... Barak an... 2009 12/9/12 10:16:5... 1
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Robotics as means to increase achievement scores in an in... Barker a... 2007 12/9/12 10:17:3... 1
Teaching introductory Java through LEGO MINDSTORMS ... Barnes 2002 7/25/13 3:34:2... 1
Bringing computational thinking to K-12: what is involved a... Barr and... 2011 12/21/13 9:52:... 1
Designerly play Baynes 1994 9/10/13 6:42:1... 1
Modeling in Elementary STEM Education Bedwar... 2011 12/21/13 5:45:1... 1
Using autonomous robotics to teach science and engineeri... Beer et al. 1999 7/25/13 3:39:4... 1
Computer Science Unplugged: An enrichment and extensi... Bell et al. 2005 3/10/13 8:05:2... 1
Exploring the educational potential of robotics in schools: ... Benitti 4/2012 2/21/13 6:26:5... 1
Designerly Thinking in the Foundation Stage Benson ... 2011 9/11/13 6:44:15...
Technology in the Classroom: Learning in the Robotic Worl... Bergen 06/2001 4/18/15 6:43:2... 1
Student Learning in Challenge-Based Engineering Curricula. Berland ... 2013 3/5/14 12:30:3...
Computational thinking and tinkering: Exploration of an ear... Bers et al. 3/2014 3/5/14 12:26:4... 1
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306 items in this view

Resources

- *johnheffernan@verizon.net*
- *Kids Engineer - http://www.kidsengineer.com/*
- *Elementary Engineering - Sustaining the Natural Engineering Instincts of Children*