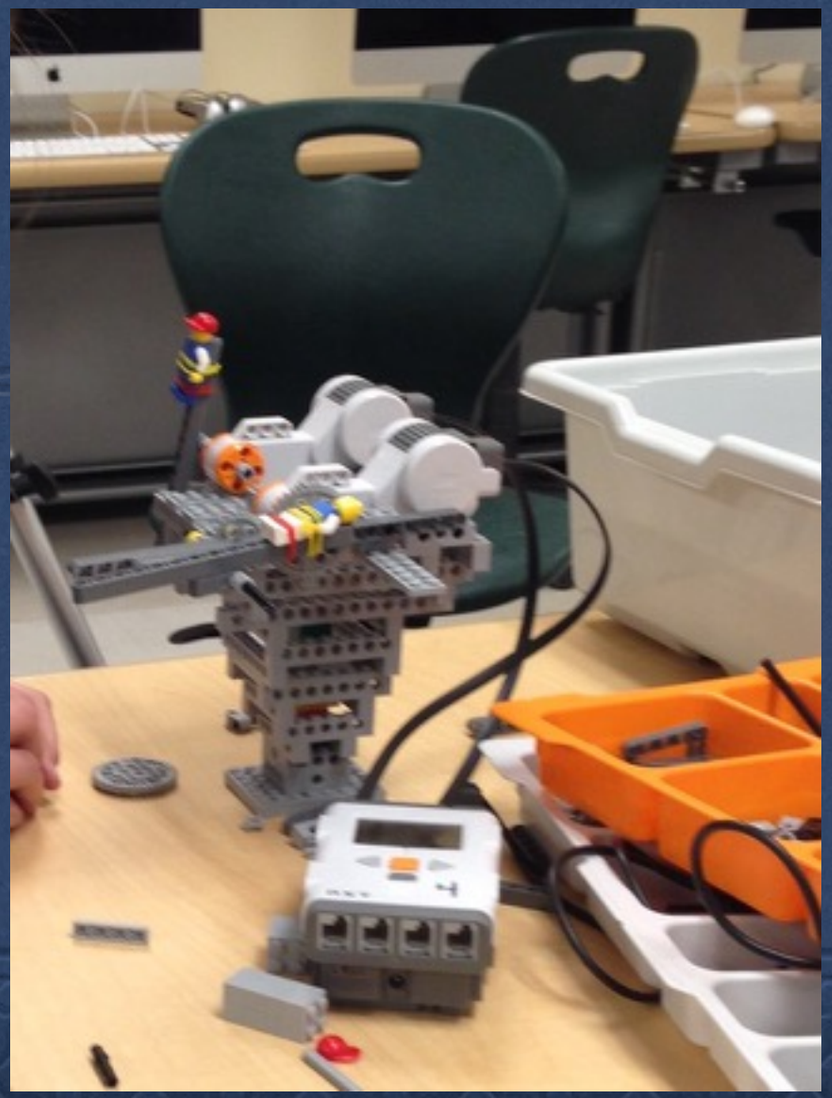
Cross Case Analysis of Elementary Engineering Task



John Heffernan - kidsengineer.com

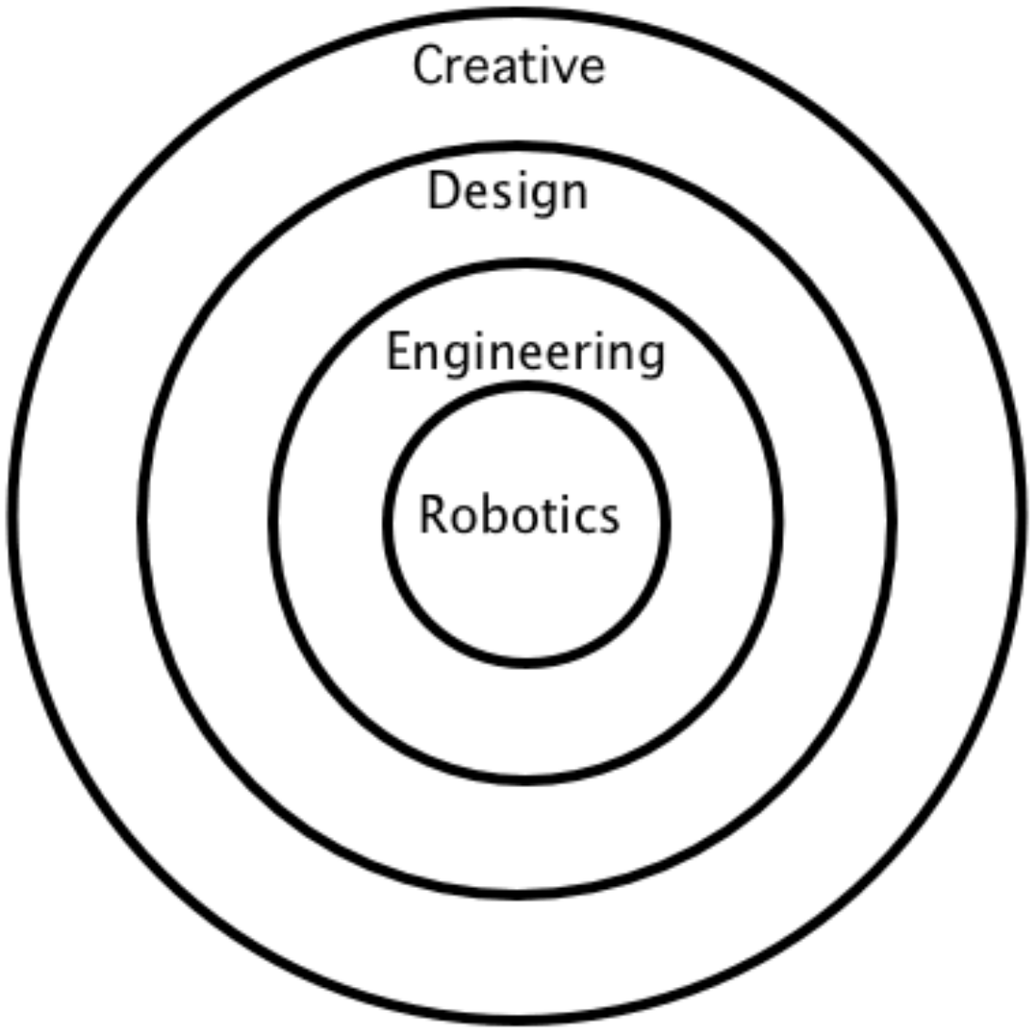
Problem Statement

- *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*

Research Questions

- *Do grade 2 and grade 6 students' engineering design processes and final products differ? If so, what are the specific differences?*
- *Do male and female students' engineering design processes and final products differ? If so, what are the specific differences?*
- *If differences are not seen by gender and grade level, what relationships do explain the differing final products and engineering design processes of elementary students?*

Literature Review

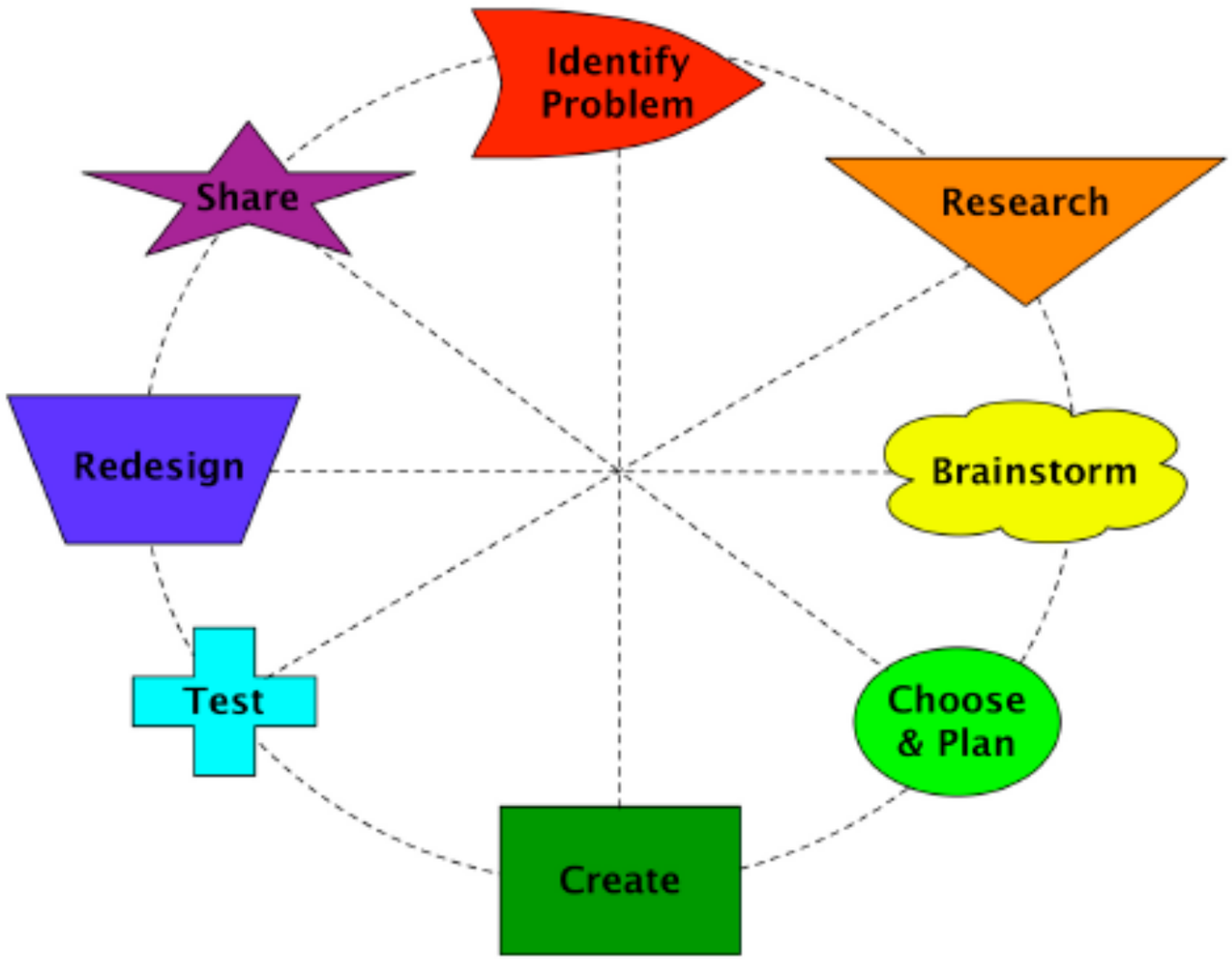


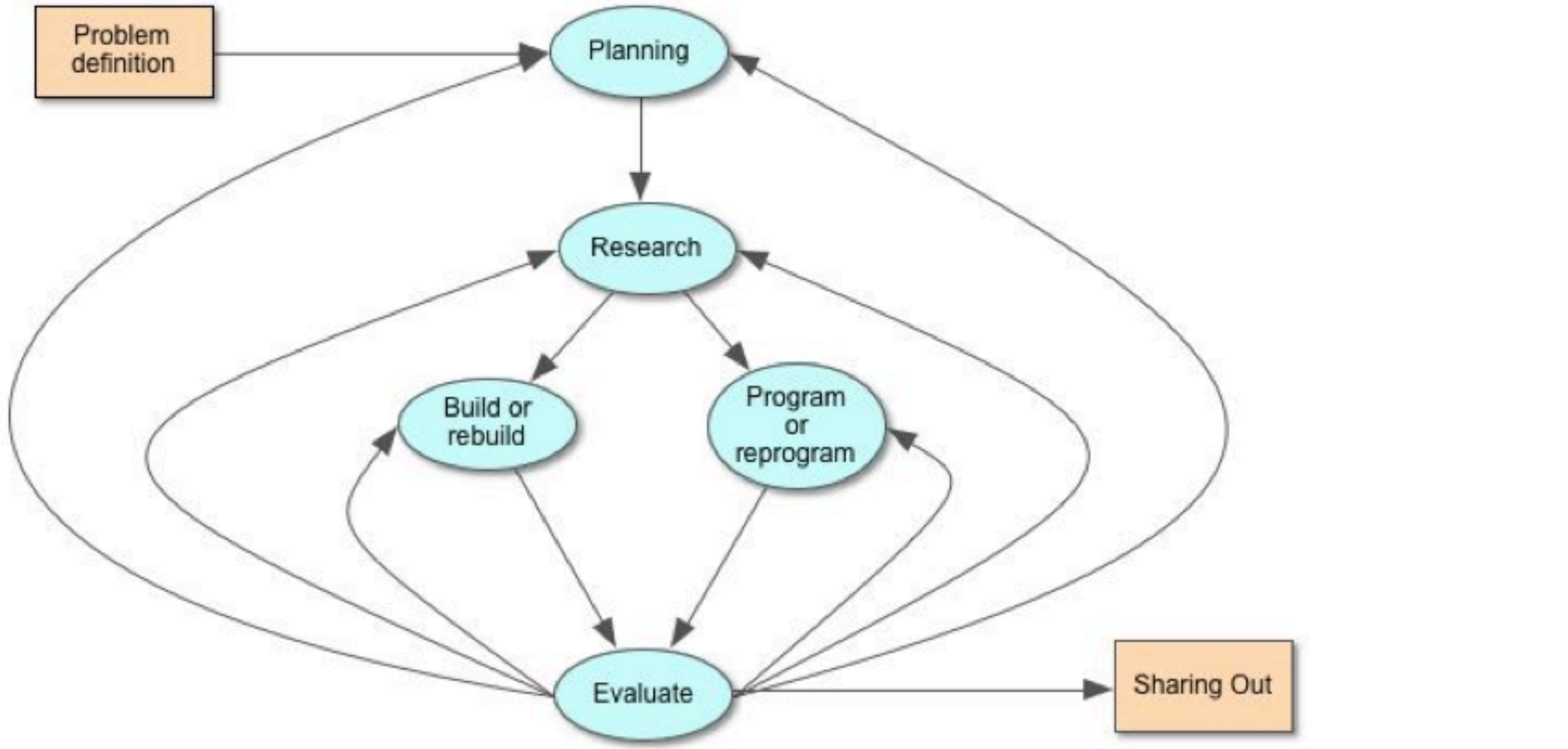
Existing EDP Research

"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."

Portsmore (2011)

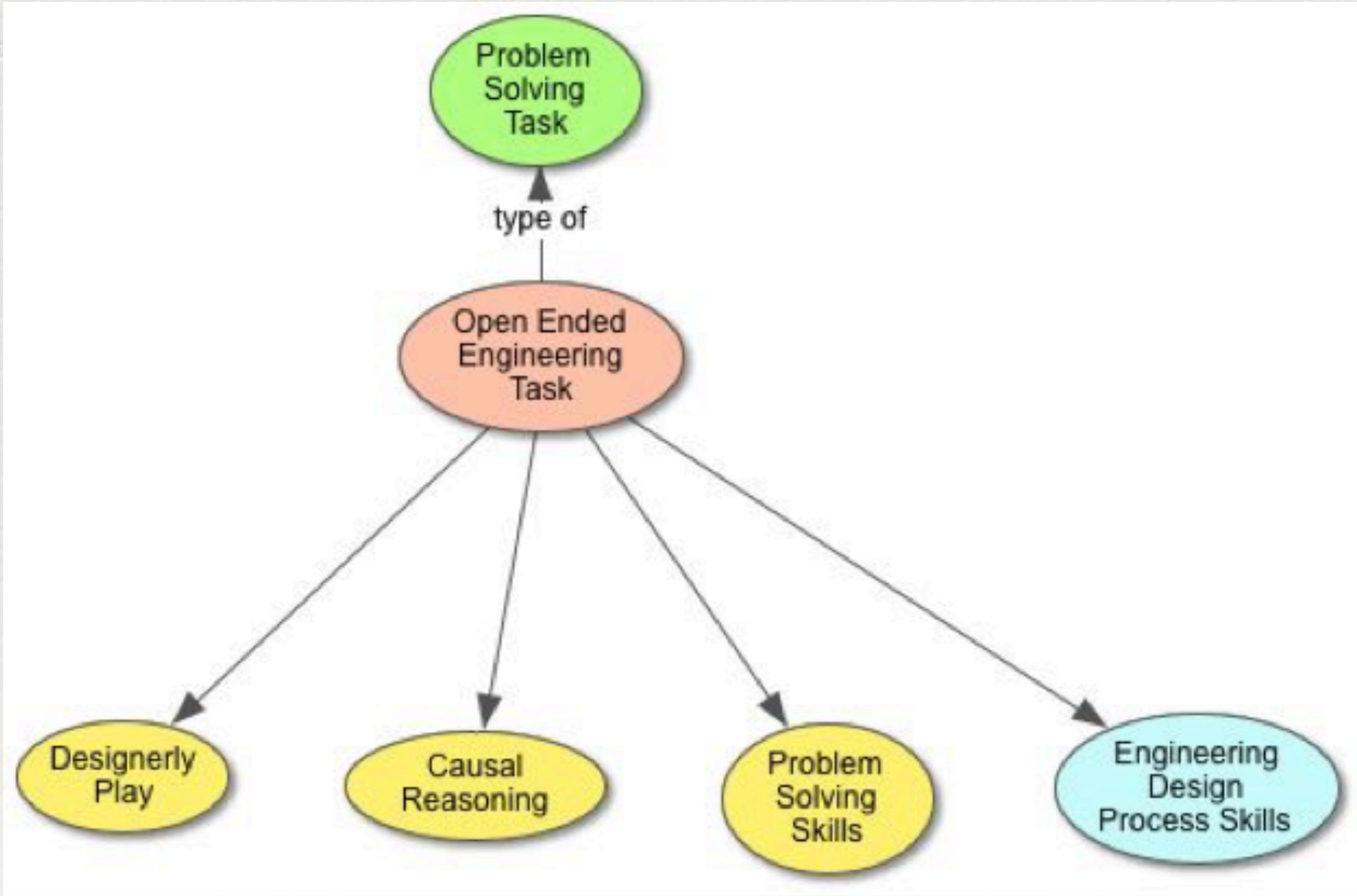
Engineering Design Process





Engineering design process model for this study

Initial Conceptual Framework

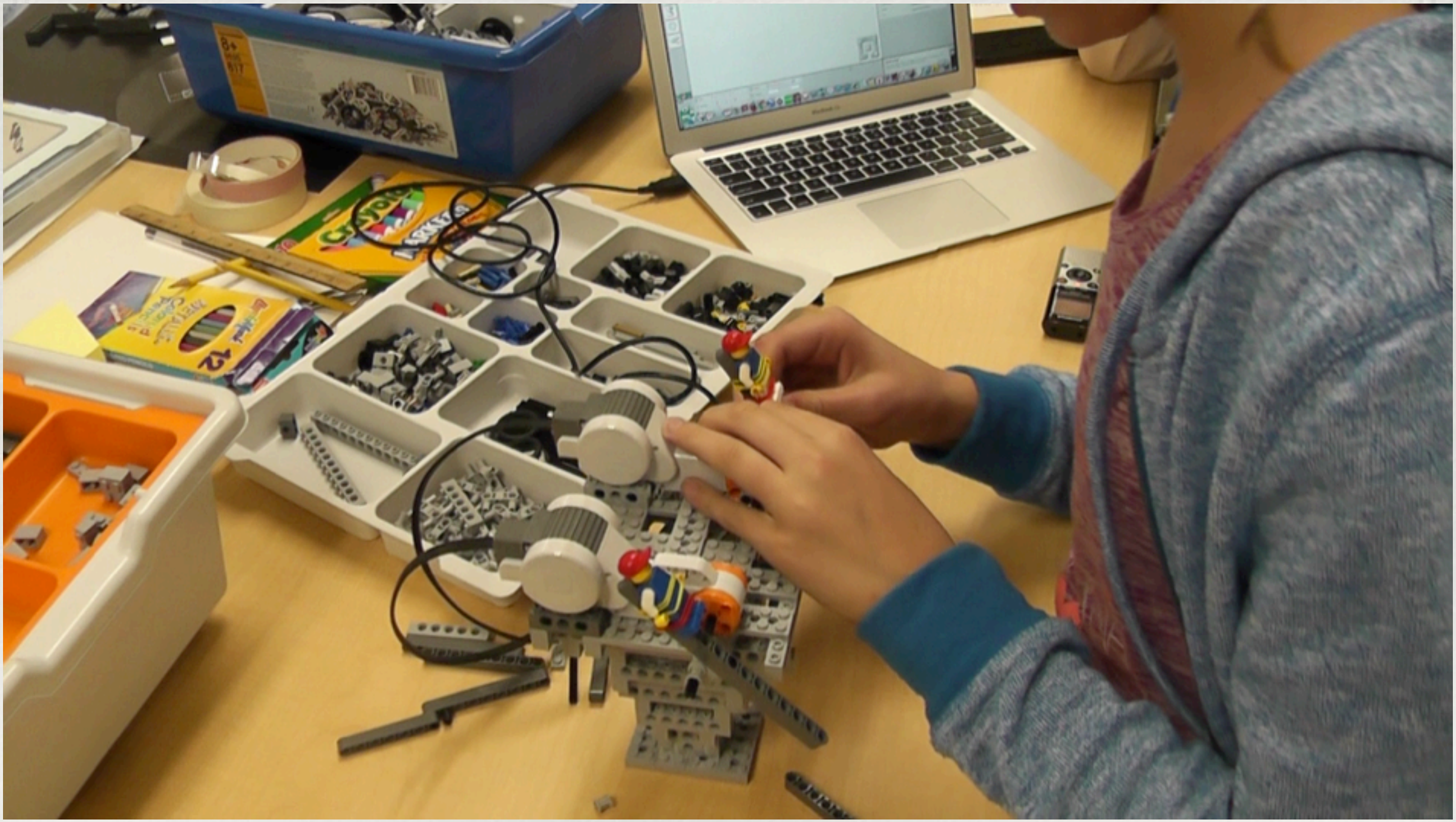


Methodology

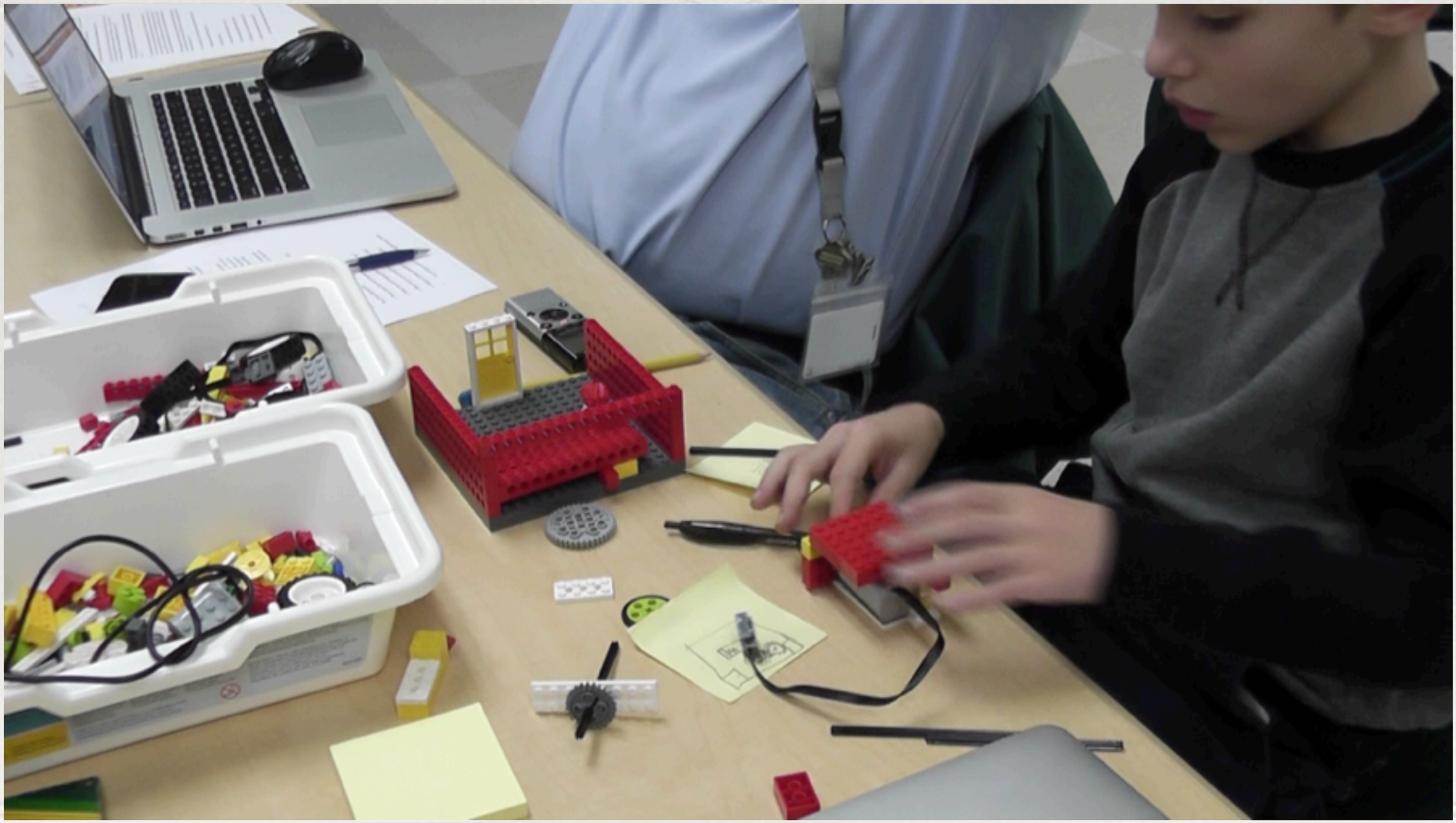
- *Qualitative, Cross Case, Cross-Sectional*
- *Semi-clinical video interview (Ginsburg, 1997)*
- *Talk aloud protocol (Ericsson & Simon, 1980)*

- *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*
- *All students started with curriculum in K*
- *Qualitative analysis of EDP, finished rides, and EDP related codes and activity*

Girl 5 Snowball Effect

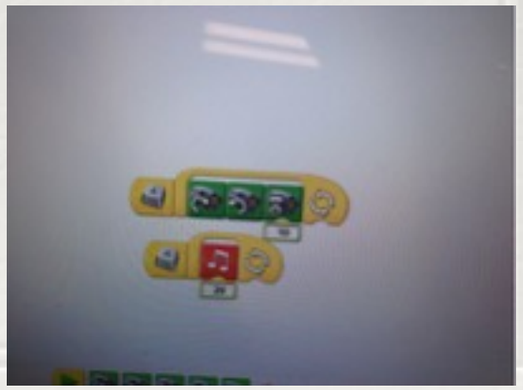


Boy 8 Learning Moment



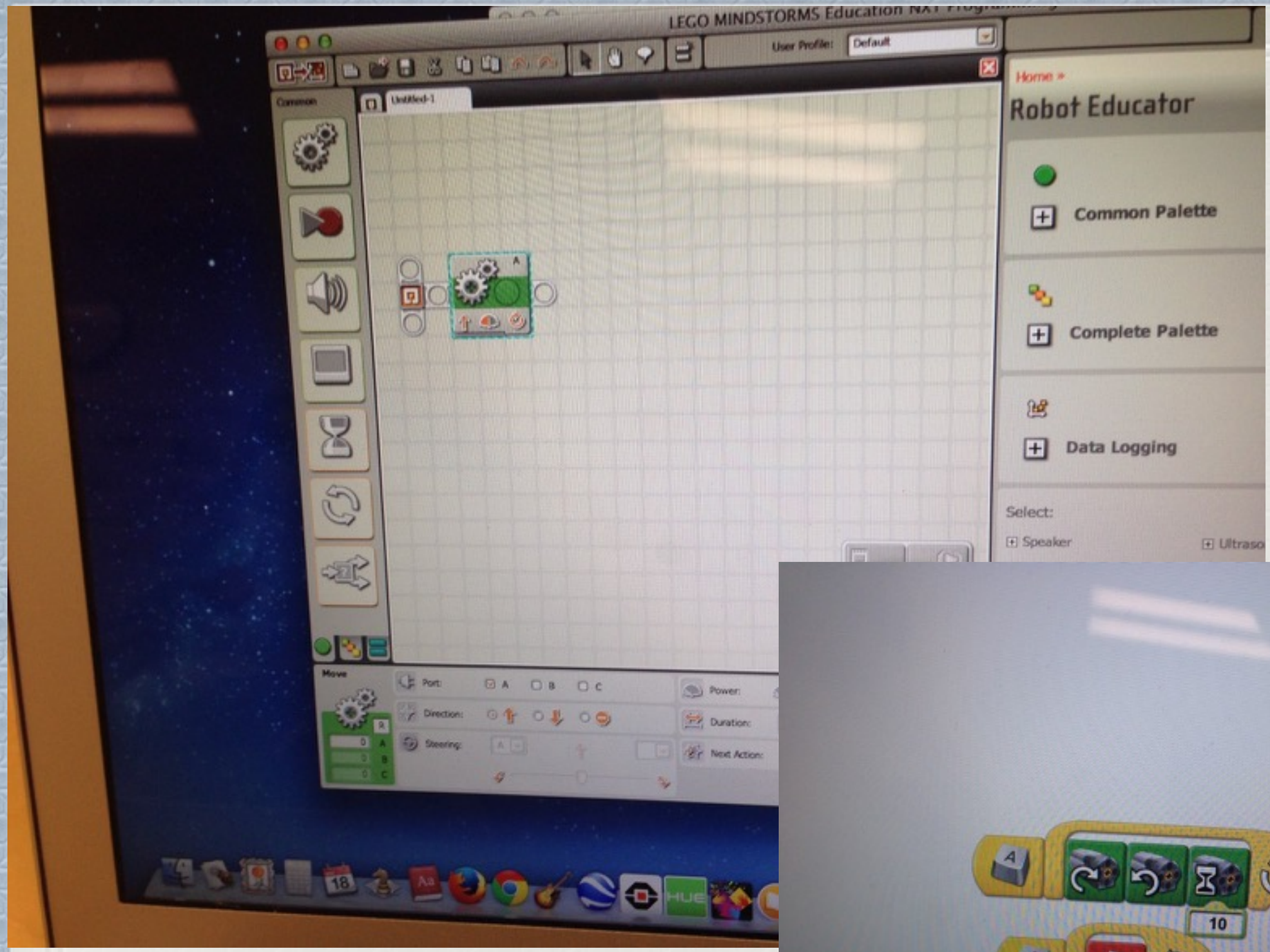
Data Collection

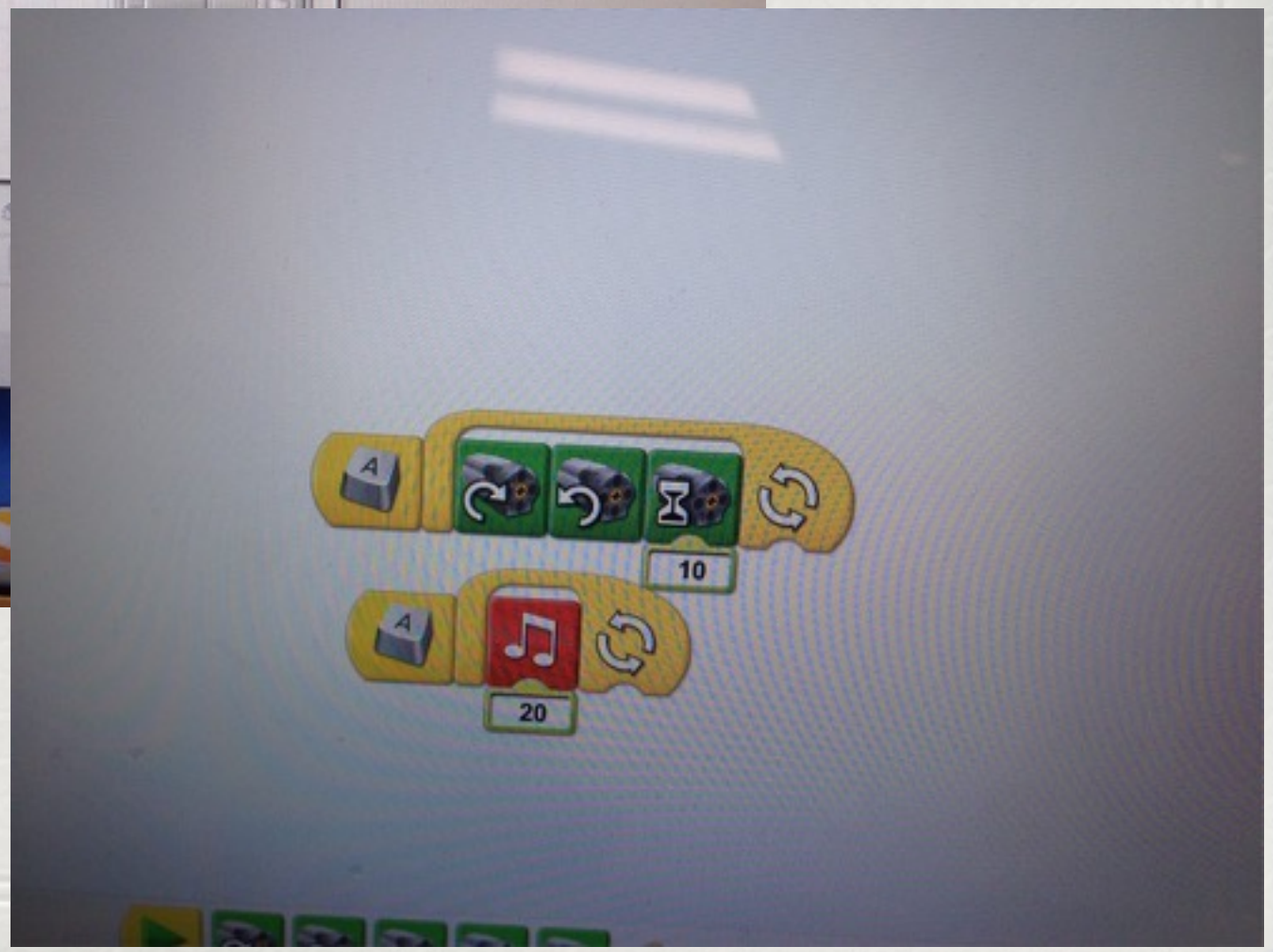
- *Warm up task (roof)*
- *Programs*
- *Photos of model*
- *Design data for each finished model*
- *Video tape of sessions - yielded EDP and EDP related data*



Data Collection Results

- *2 hours of warm task and 8.5 hours of main t…*
- *Some challenges with subjects and videotaping*
- *Completed November-December 2015*
- *Multiple "track" issues with building and talking*
- *Transcription, time-stamping, segmenting, coding*
- *312 pages of segmented, coded transcripts*

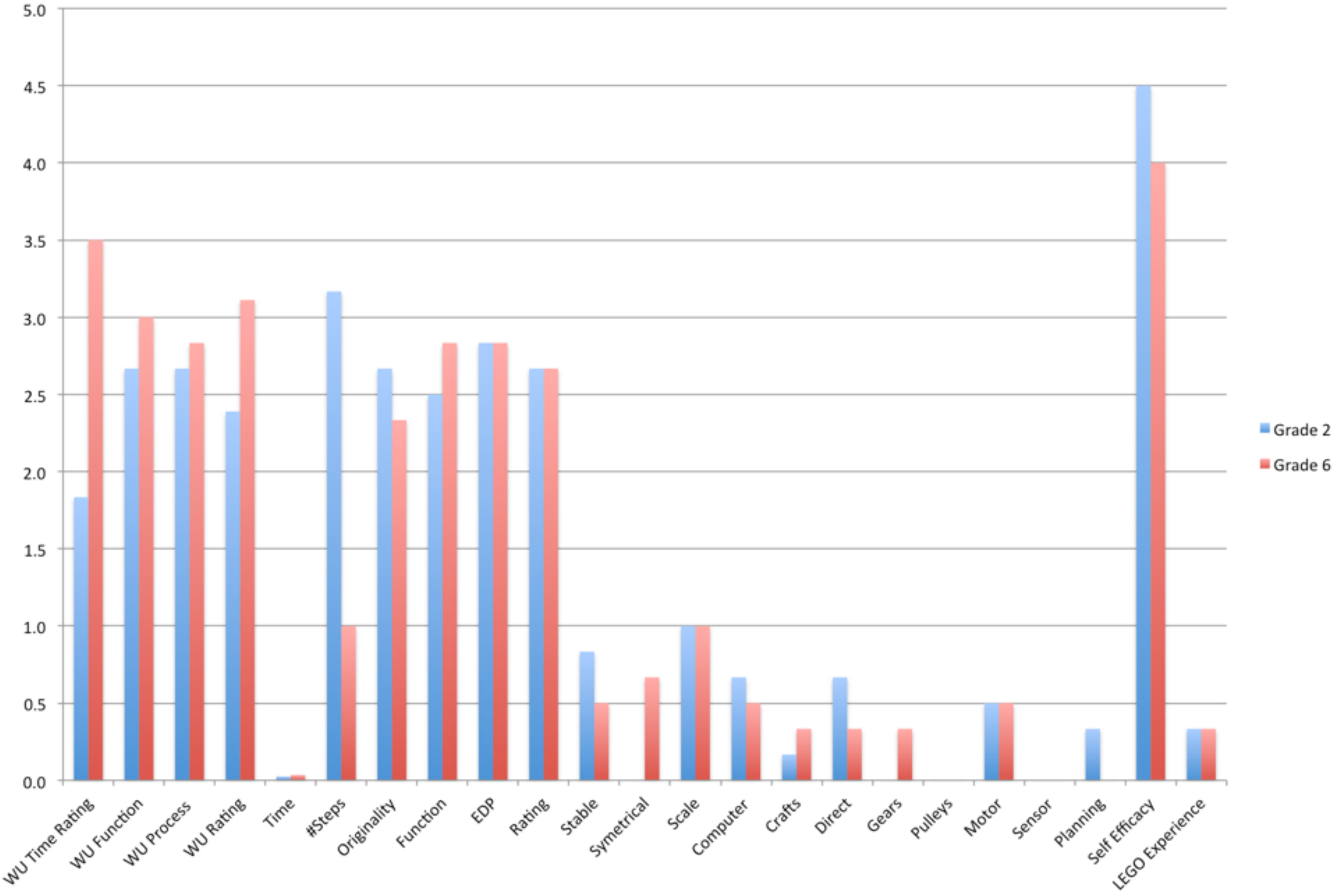

LEGO MINDSTORMS Education NXT
User Profile:
Default
Home »
Robot Educator
Common Palette
Complete Palette
Data Logging
Select:
Speaker
Move
Port:
Direction:
Steering:
Power:
Duration:
Next Action:


A
10
A
20

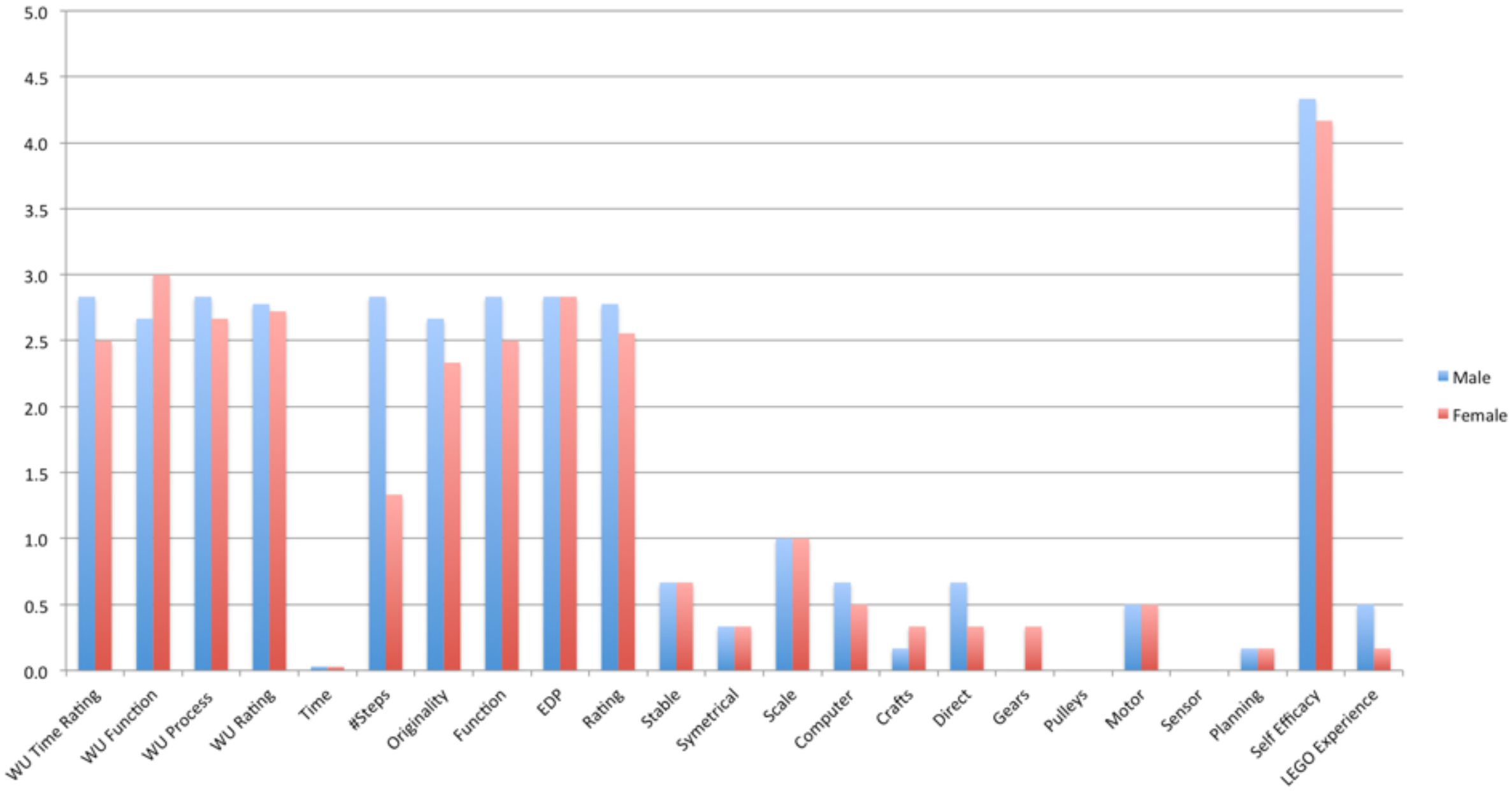
Finished Model Design Data

- *Warm Up Task - time, function, process (rubric)*
- *Ride quality - originality, function, process (rubric)*
- *Finished Model Design Data - #parts, time, use of different parts (motors, computer, crafts, sensors, gears, etc), stability, symmetry, scale*
- *Self Efficacy*

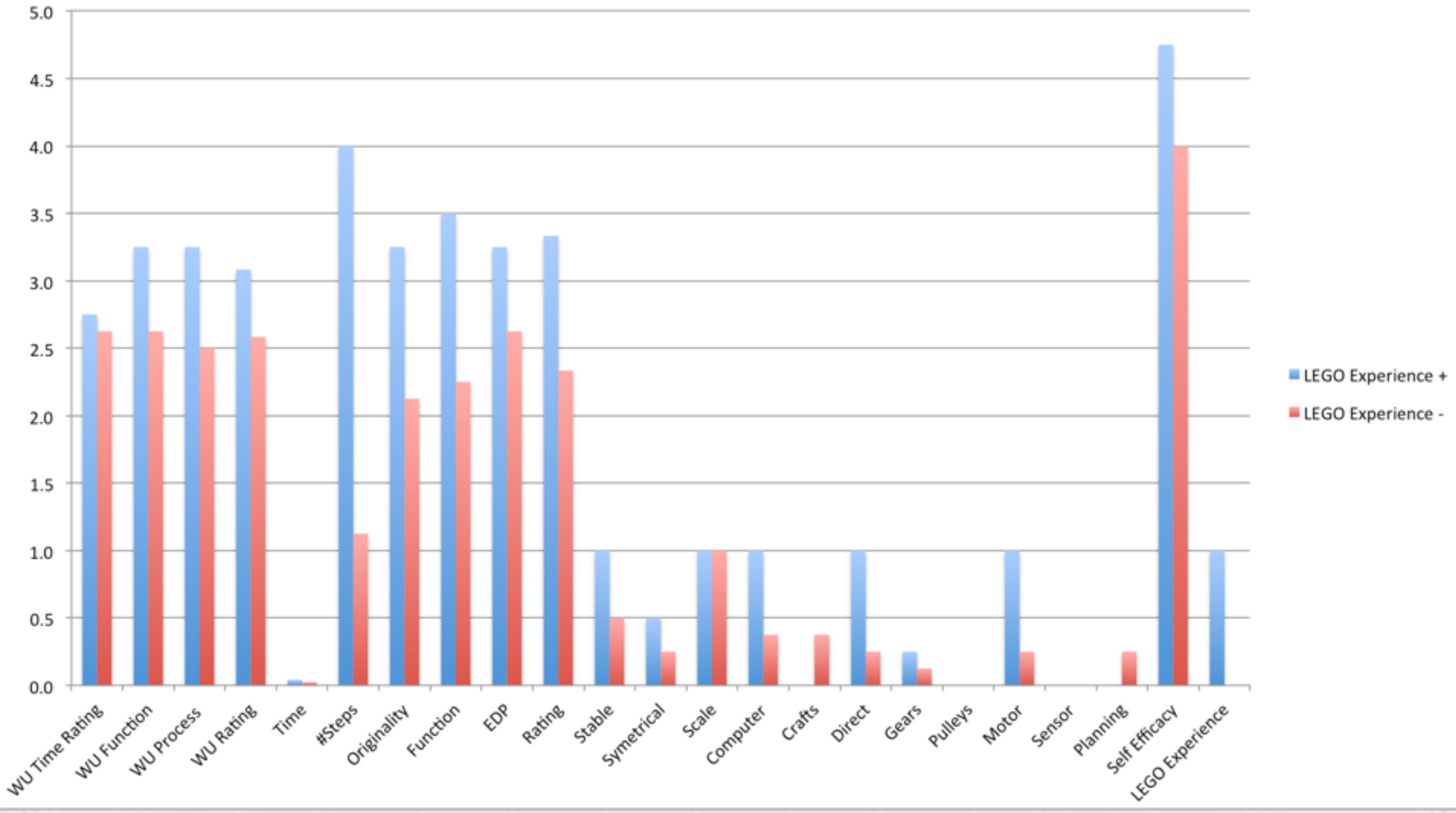
Finished Model Design Data by Grade Level



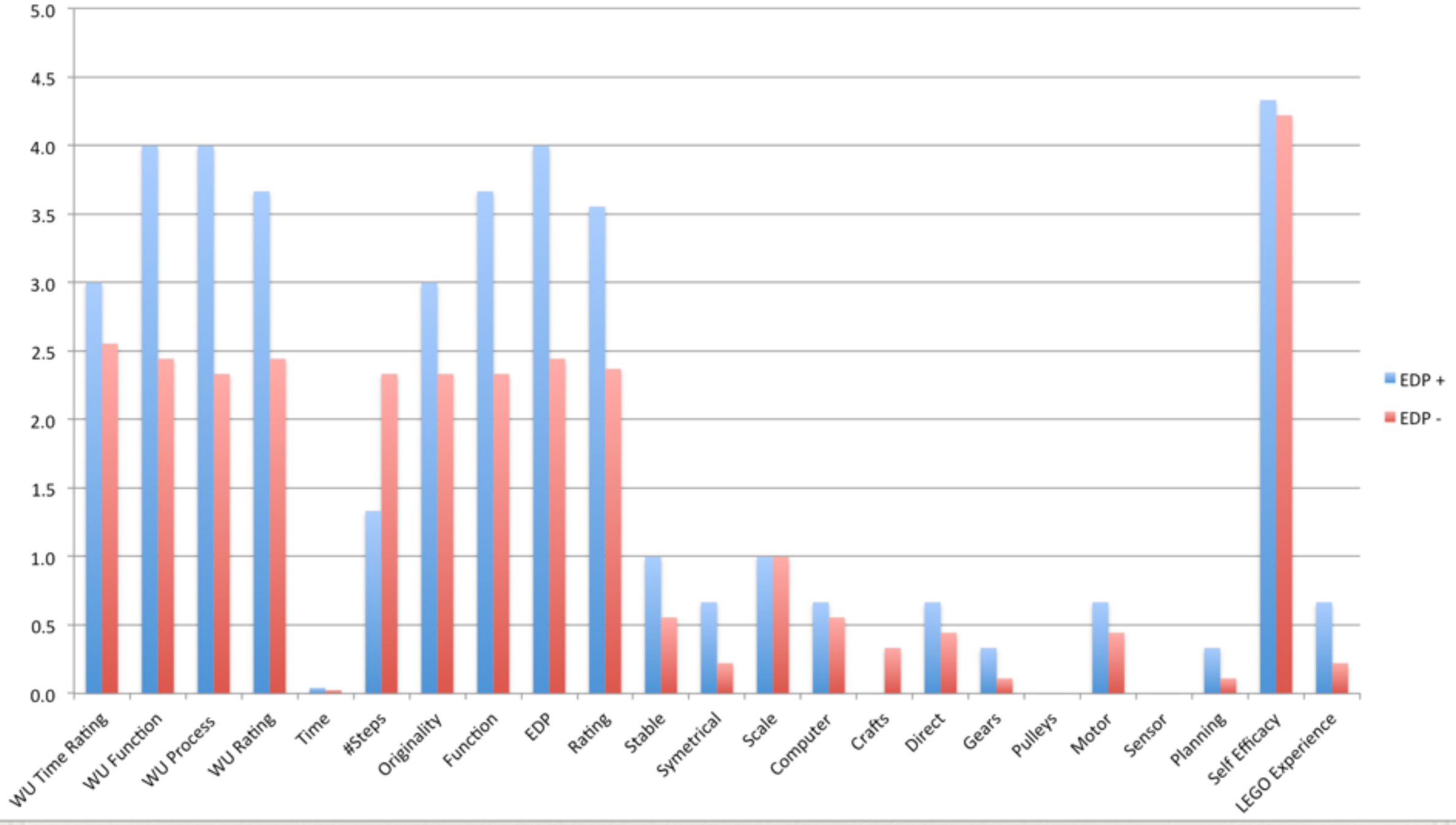
Finished Model Design Data by Gender



Finished Model Design Data by LEGO Experience



Finished Model Design Data by EDP+/-

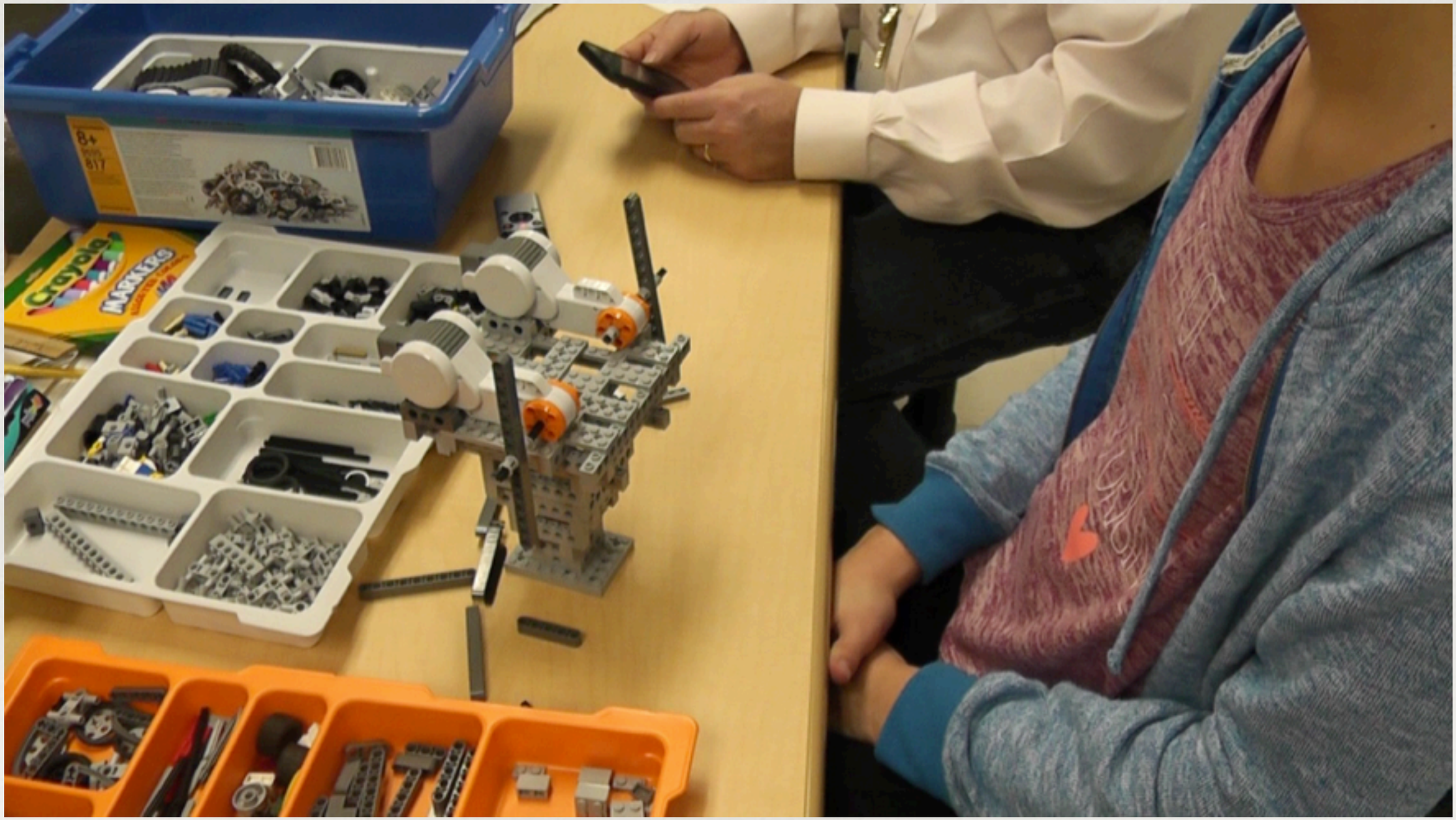


Finished Model Analysis Summary

- *No major differences by gender or grade level!*
- *Differences noted **related to** LEGO Experience and EDP process*
- *But what exactly are the underlying factors?*
- *Would EDP timelines shed any light? Would they differ by gender or grade level?*

EDP Process Analysis

- *EDP Timeline Graphs produced for all 12 subjects*
- *Compared EDP timeline graphs (see examples)*
- *Also tabulated EDP phase frequencies, total phase times, and durations of each phase (see examples)*
- *First, some background and methodology*


8+
817
Crayola
Markers

Segmented Sample

[00:32:41] {moving}

[00:32:49] {no_activity}

Researcher: Yeah. There's always a challenge.

[00:32:51[{searching} Girl 05: Hmm. Trying to think about this. If I have this, that, that'll be upright. Yeah, that seems like it'll work. If I put one of these on each, I hope this will work. Put this on that, and that will run with ...

[00:32:53] {connecting}

[00:33:22] Girl 05: How am I going to connect that? It'll be like ...

[00:33:26] {moving}

[00:33:28] {connecting} Girl 05: Yeah, okay.

Researcher: Great idea.

[00:33:33] {measuring} Girl 05: Okay, where did my middle ...

[00:33:37] Girl 05: Yeah. Then it'll ...

[00:33:38] {connecting}

[00:33:40] {moving}

[00:33:42] Girl 05: Weird.

Coded and Segmented Sample

Girl 5 Segmented Coded Example

[00:32:41] [EVALUATE] {moving}

[00:32:49] [PLAN] {no_activity}

Researcher: Yeah. There's always a challenge.

[00:32:51] [PLAN] {searching} Girl 05: Hmm. Trying to think about this.

[00:32:57] [RESEARCH] Girl 5: If I have this, that, that'll be upright. Yeah, that seems like it'll work. If I put one of these on each, I hope this will work. Put this on that, and that will run with ...

[00:32:53] {connecting}

[00:33:22] Girl 05: How am I going to connect that? It'll be like ...

[00:33:26] {moving}

[00:33:28] [BUILD] {connecting} Girl 05: Yeah, okay.

Researcher: Great idea.

[00:33:33] {measuring} Girl 05: Okay, where did my middle ...

[00:33:37] Girl 05: Yeah. Then it'll ...

[00:33:38] {connecting}

[00:33:40] [EVALUATE] {moving}

[00:33:42] Girl 05: Weird.

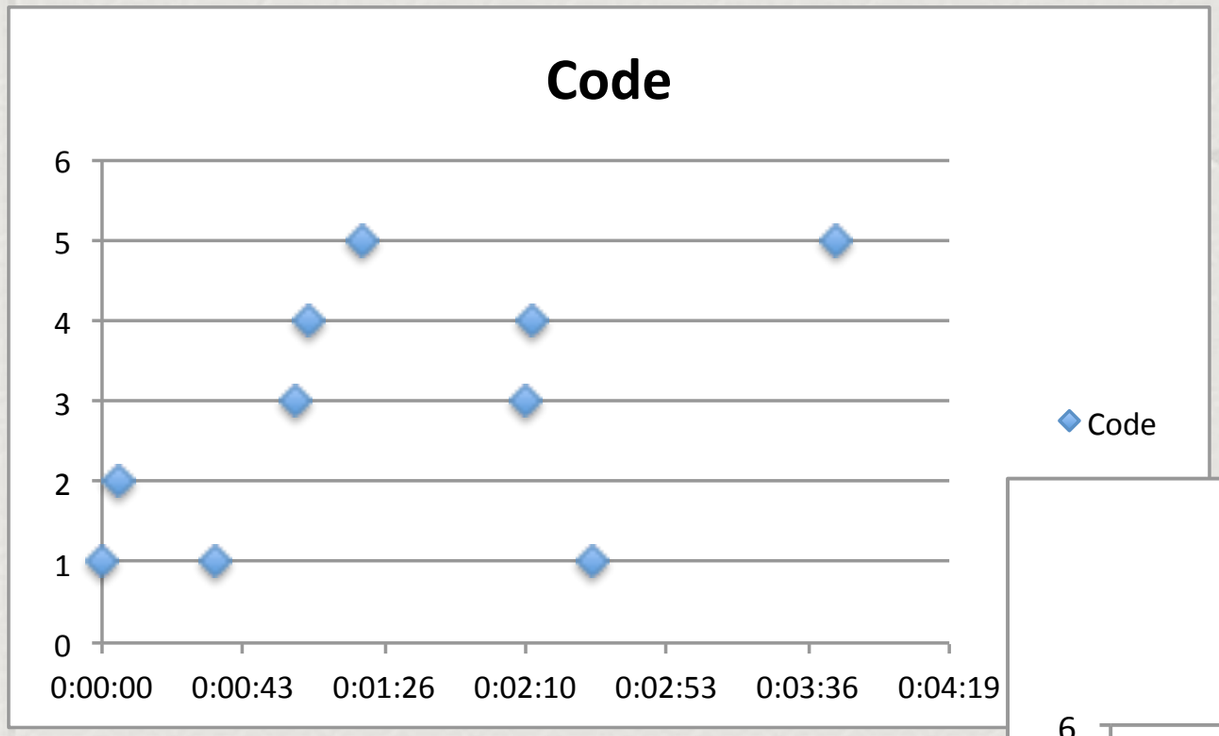
Segmenting and Coding Example

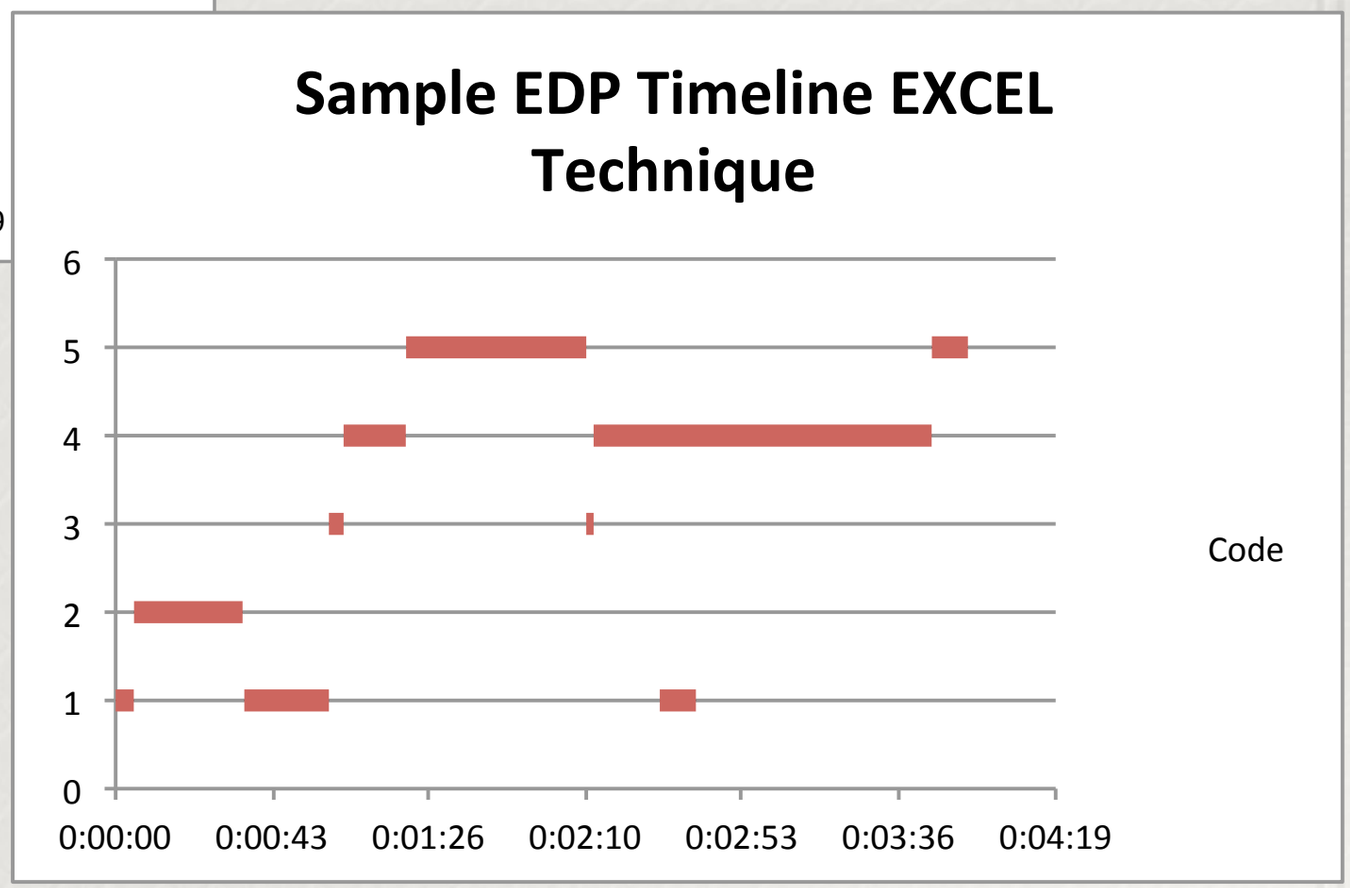
Main Code	[BUILD]	[BUILD]	[PLAN]	[RESEARCH]	
Overlapping Code (verbal, if any)		[2:PLAN]			
Verbal Segment	"I am adding a block to make the tower more stable."	"I am going to add a mini-figure later.	"I will also make a seatbelt."	"I am trying it over here."	"YES!"
Physical Segment	{search} {connect}	{connect}	{no_activity}	{connect}	{move}

EXCEL Solution

A	B	C	D	E
Start	Duration	Code	End	
0:00:00	0:00:05	1	0:00:05	
0:00:05	0:00:30	2	0:00:35	
0:00:35	0:00:24	1	0:00:59	
0:00:59	0:00:04	3	0:01:03	
0:01:03	0:00:17	4	0:01:20	
0:01:20	0:00:50	5	0:02:10	
0:02:10	0:00:02	3	0:02:12	
0:02:12	0:01:33	4	0:03:45	Overlap
0:02:30	0:00:10	1	0:02:40	Overlap
0:03:45	0:00:10	5	0:03:55	
0:03:55				

EXCEL Solution 2



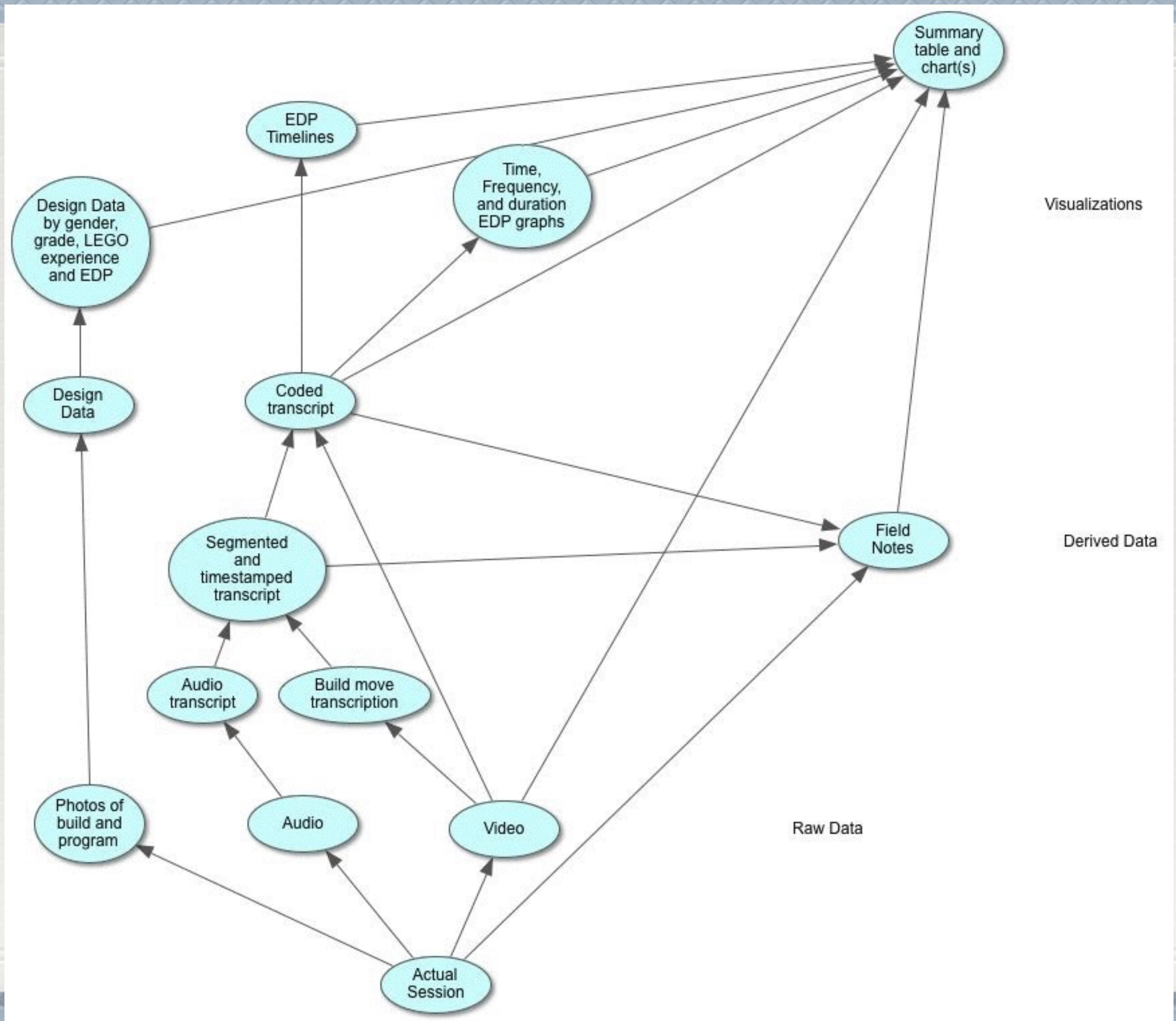


Big Ideas - Methodology

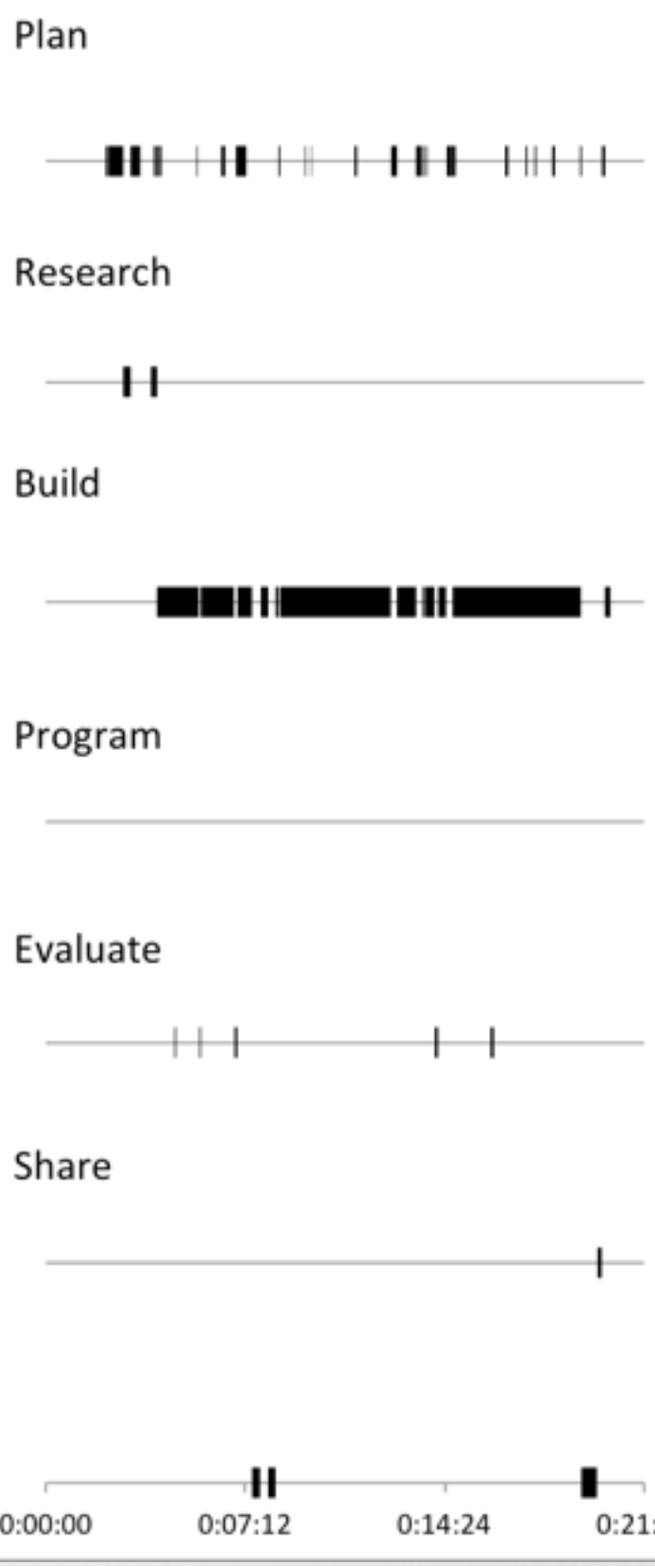
- *Talk aloud and clinical at the same time has some tradeoffs (richness of data, questions influence building)*
- *Sharing out caused reflection and changes*
- *Physical activity segmenting - separate from EDP analysis*
- *Overlapping EDP phases - needed to be accounted for*

IRR

- *Over 80% (83.3%) intercoder reliability was achieved using Krippendorff's alpha (Freelon, 2010; Krippendorff, 2007) on 20% of the video.*
- *The 80% threshold same or better than similar studies with college level engineering students (Atman et al., 2005).*
- *3% of the video was coded together.*
- *7% was coded independently with the two coders meeting after to resolve differences and refine the code definitions.*
- *10% was coded independently and used to calculate the intercoder reliability.*
- *Researcher coded the remaining 80% of the transcripts.*
- *Systemic errors counted once. Given frequently separate verbal and physical tracks, the reliability achieved was considered high.*
- *A total of 312 pages of coded transcripts were produced.*

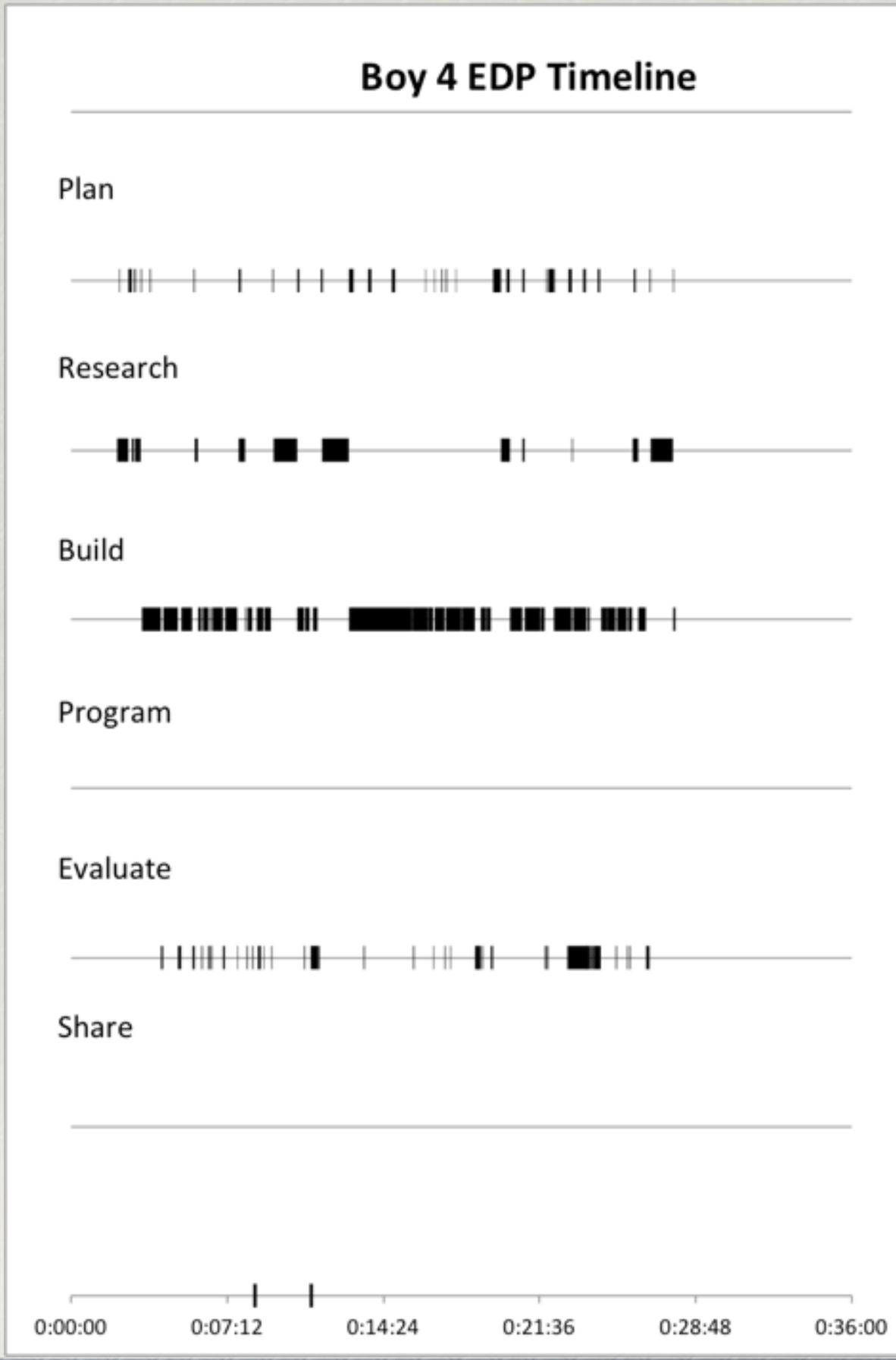

Summary table and chart(s)
EDP Timelines
Time, Frequency, and duration EDP graphs
Design Data by gender, grade, LEGO experience and EDP
Visualizations
Design Data
Coded transcript
Field Notes
Derived Data
Segmented and timestamped transcript
Audio transcript
Build move transcription
Photos of build and program
Audio
Video
Raw Data
Actual Session

Boy 3 EDP Timeline



Low complexity, low tools

Gender Subject	Boy 3
Grade Level	6
Model Rating	2.0
Prelim EDP Rating	2
LEGO Experience	0
Motor	0
SK	Low
Math/Science	Low
Design Principles	Low
EDP Process	Low
CR	Medium
Plan-Ahead	Low
CF	Medium

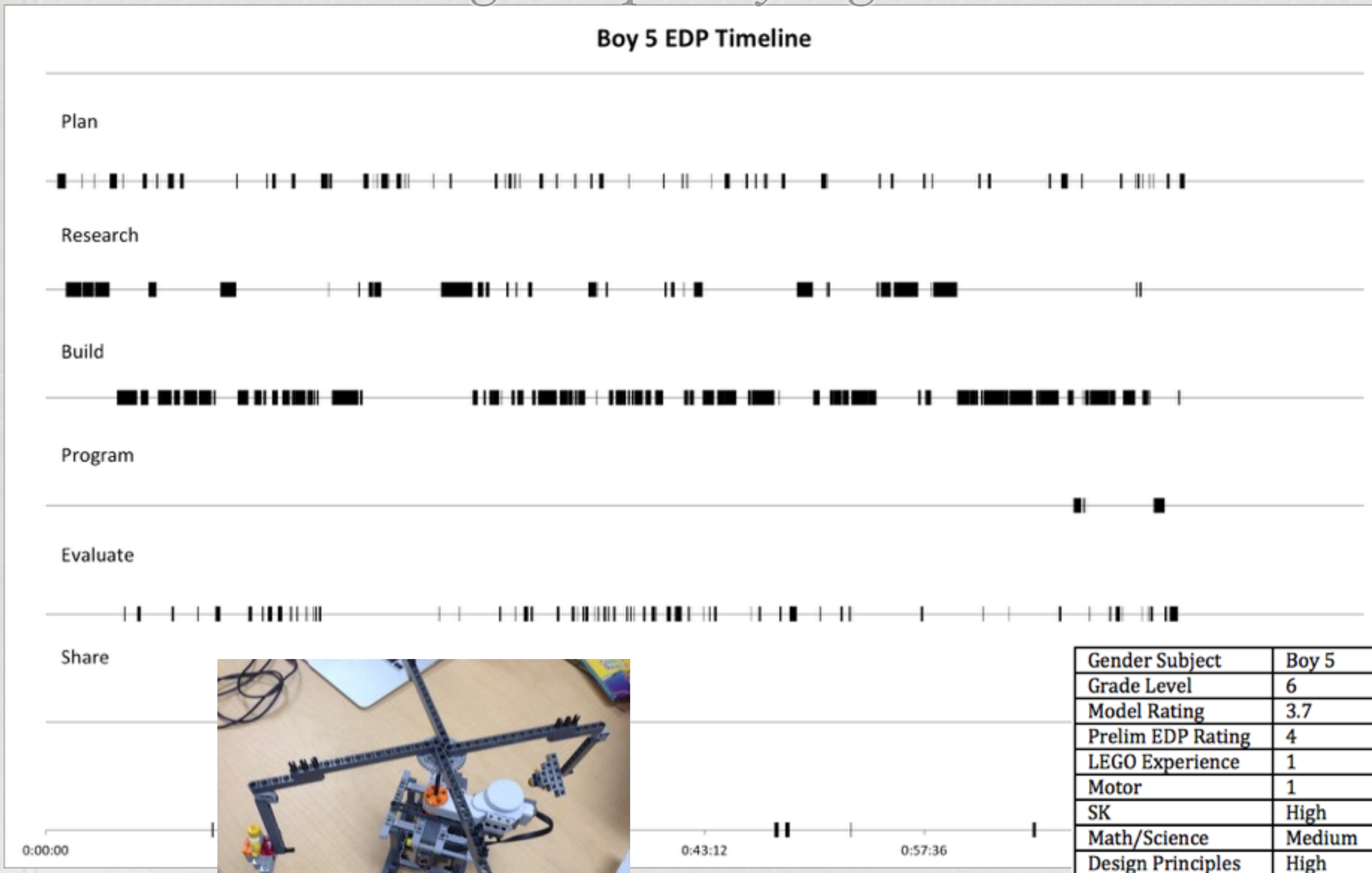


Gender Subject	Boy 4
Grade Level	6
Model Rating	2.7
Prelim EDP Rating	3
LEGO Experience	0
Motor	0
SK	High
Math/Science	Medium
Design Principles	High
EDP Process	Medium
CR	High
Plan-Ahead	Low
CF	Medium

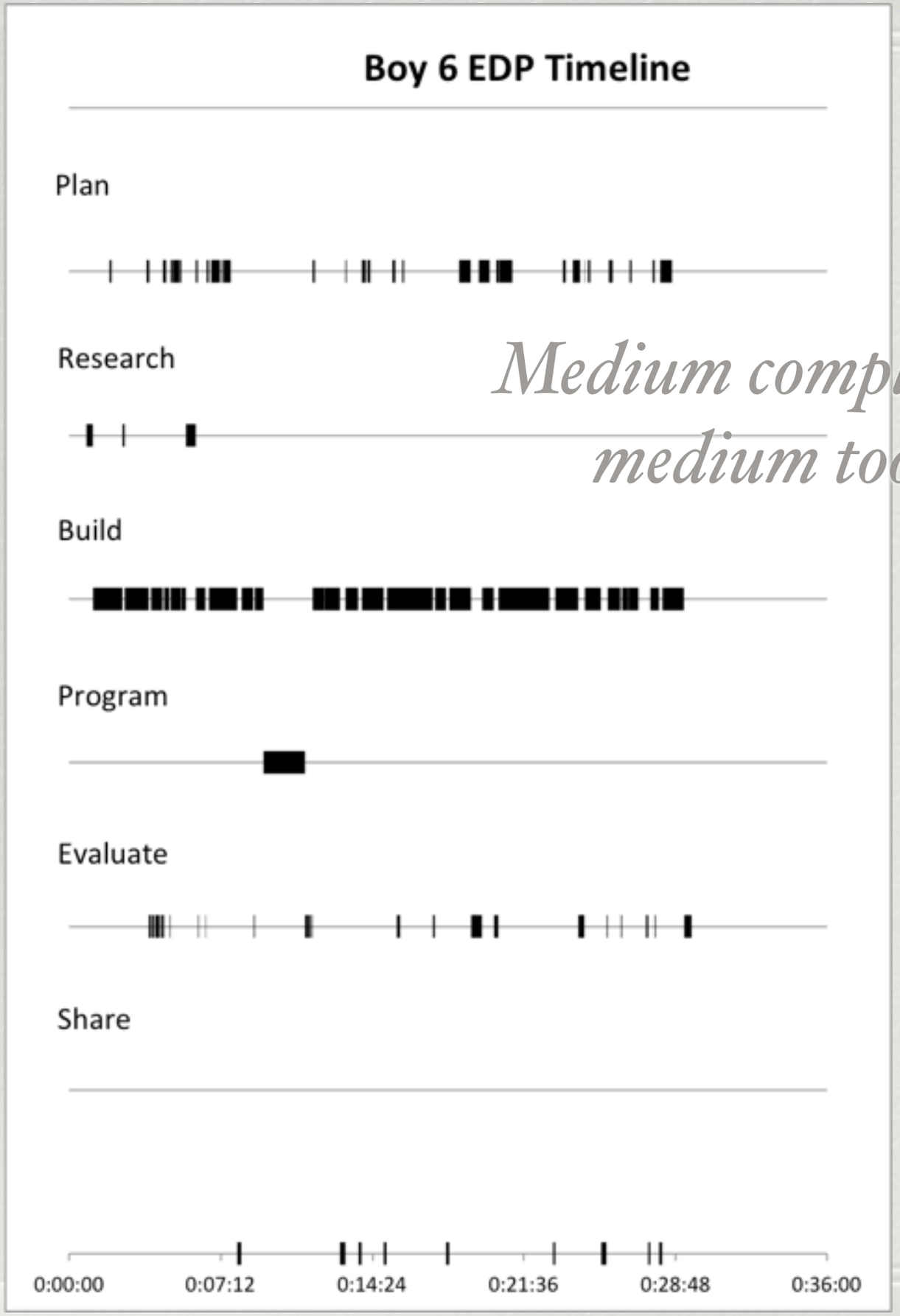
Low complexity, medium tools*

** close to medium complexity*

High complexity, high tools

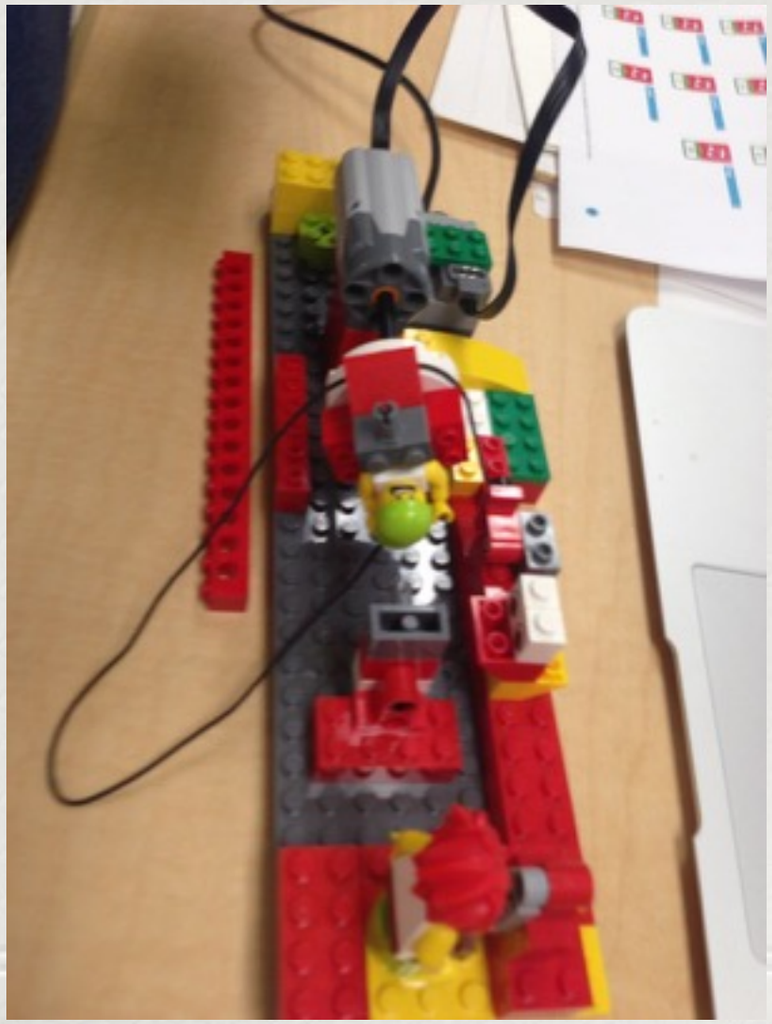


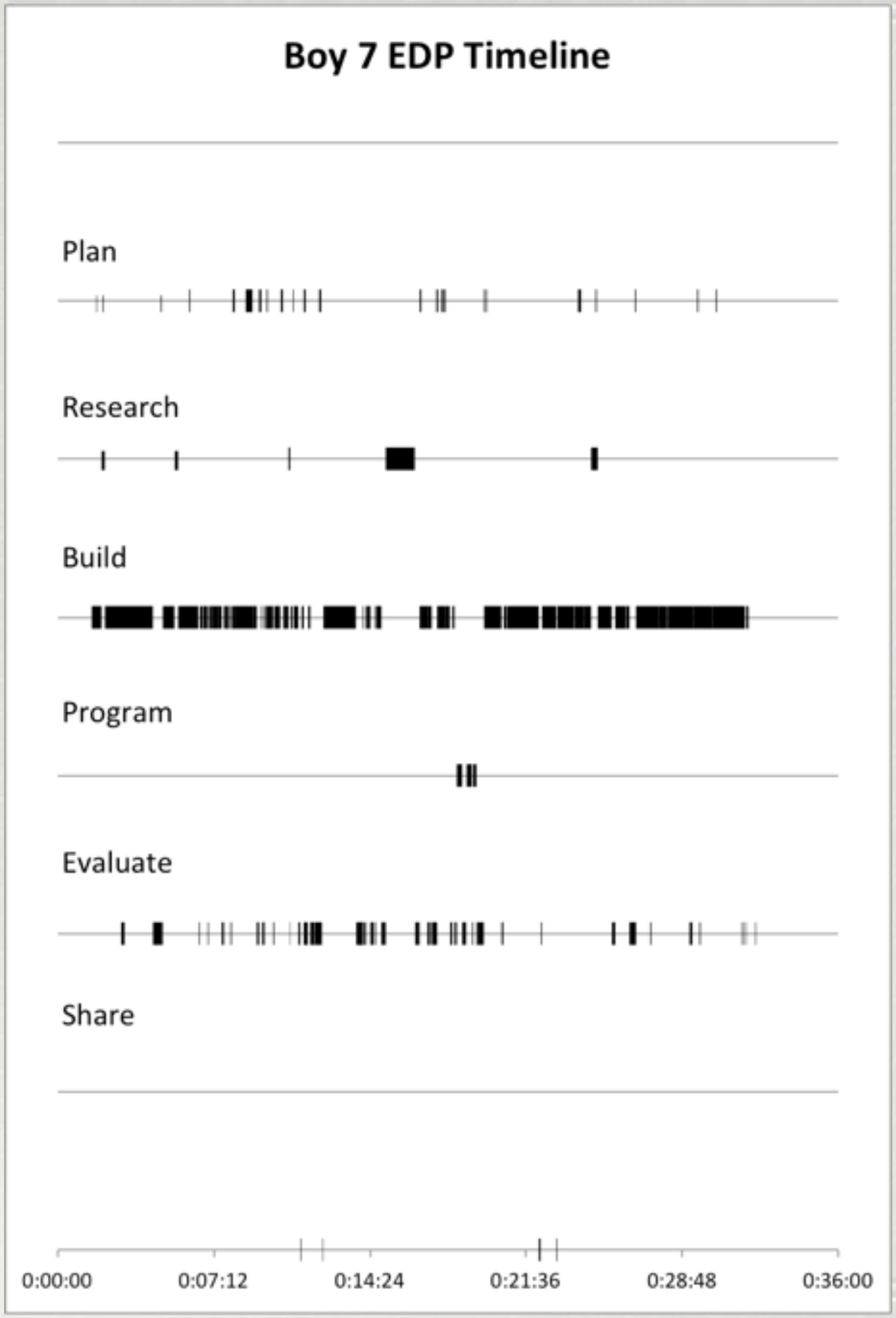
Gender Subject	Boy 5
Grade Level	6
Model Rating	3.7
Prelim EDP Rating	4
LEGO Experience	1
Motor	1
SK	High
Math/Science	Medium
Design Principles	High
EDP Process	Medium
CR	High
Plan-Ahead	High
CF	Medium



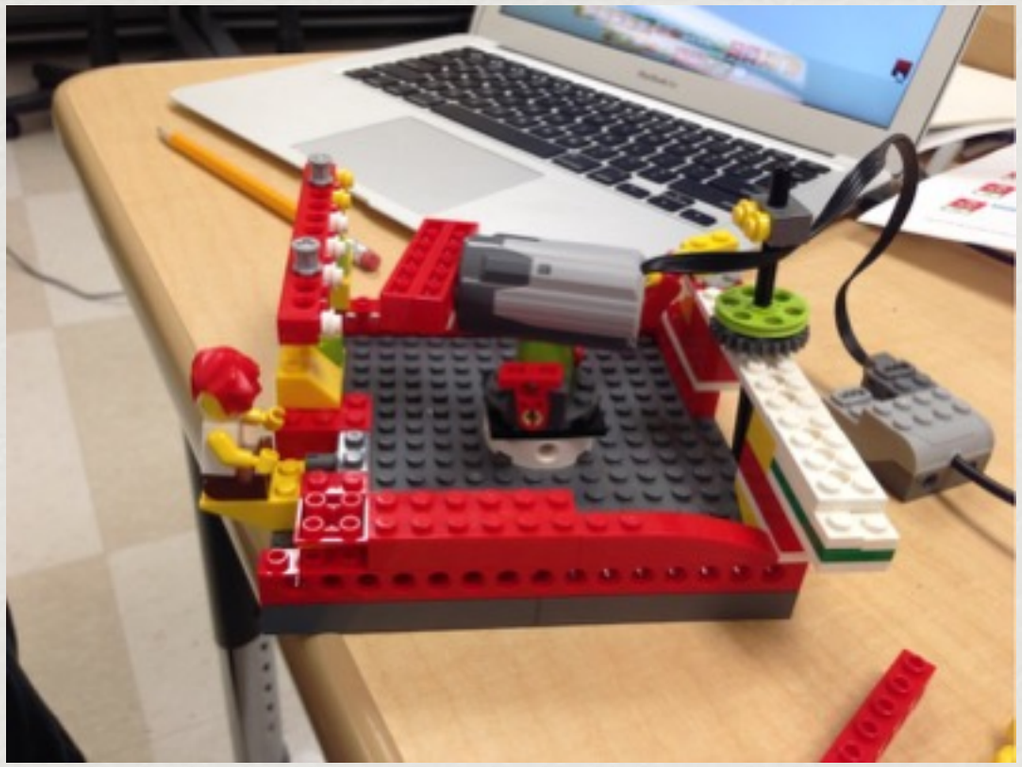
Medium complexity, medium tools

Gender Subject	Boy 6
Grade Level	2
Model Rating	3.0
Prelim EDP Rating	3
LEGO Experience	1
Motor	1
SK	Medium
Math/Science	Low
Design Principles	Low
EDP Process	High
CR	High
Plan-Ahead	Low
CF	High



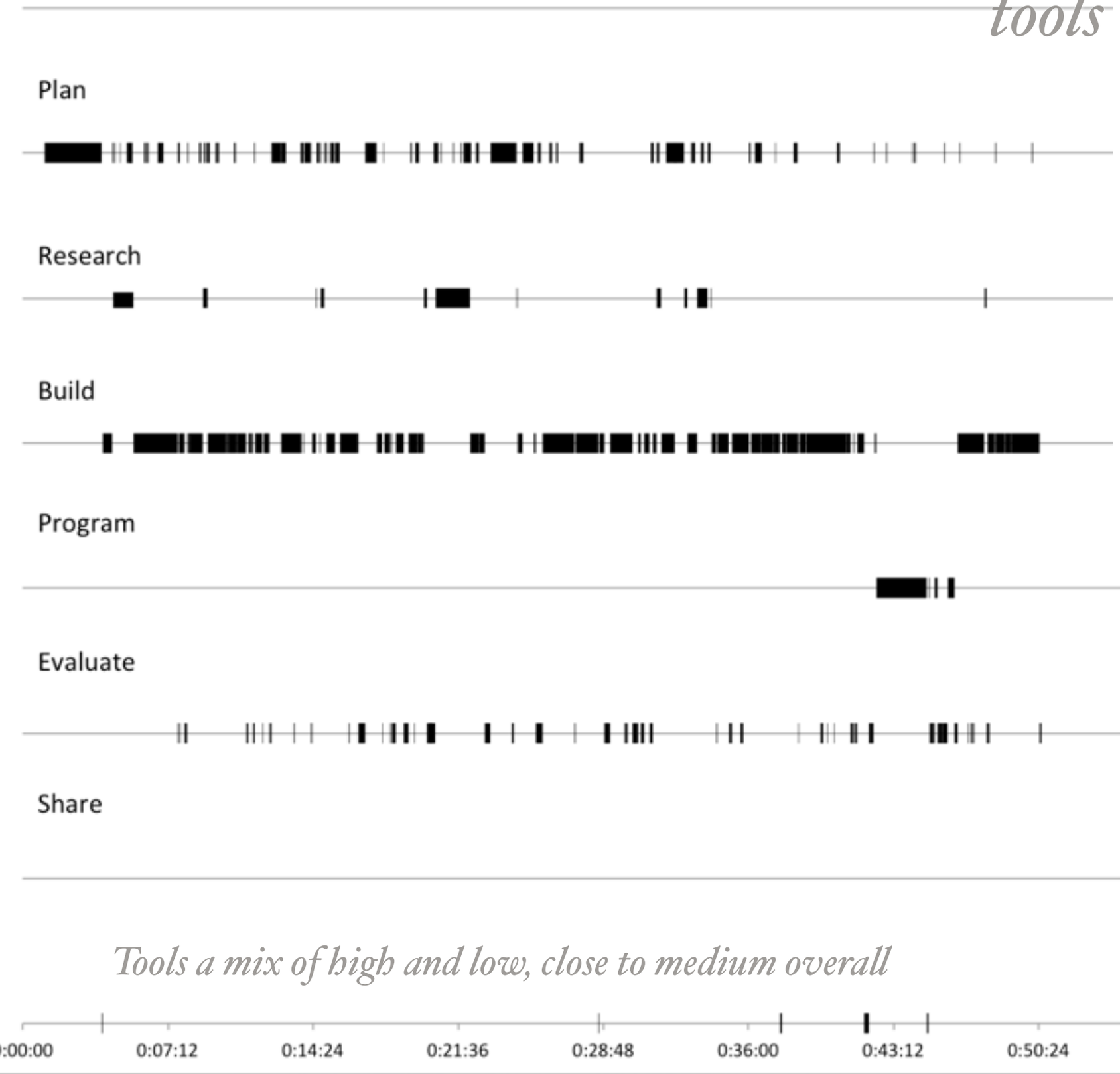


Medium complexity, medium tools

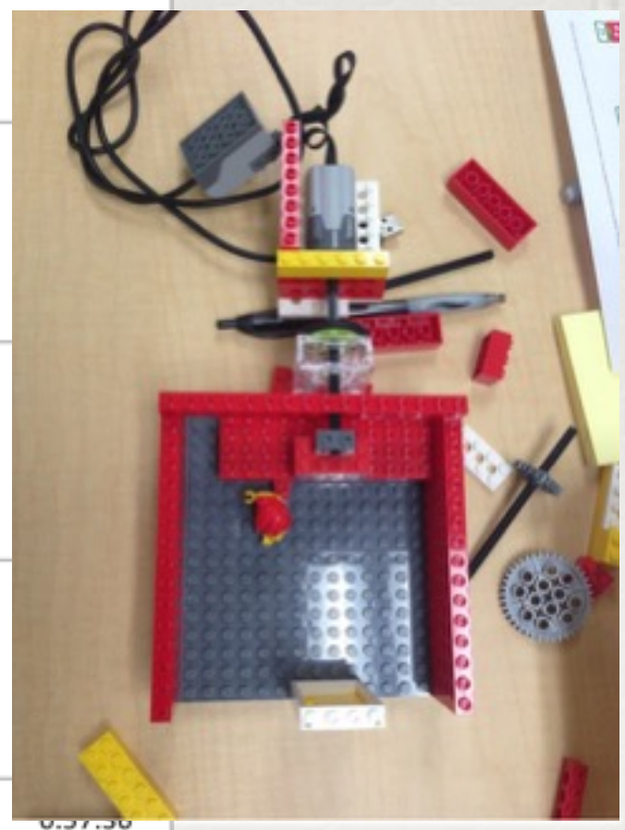


Gender Subject	Boy 7
Grade Level	2
Model Rating	3.0
Prelim EDP Rating	3
LEGO Experience	1
Motor	1
SK	Medium
Math/Science	Low
Design Principles	Medium
EDP Process	Medium
CR	Medium
Plan-Ahead	Low
CF	Low

Medium complexity, Low tools*

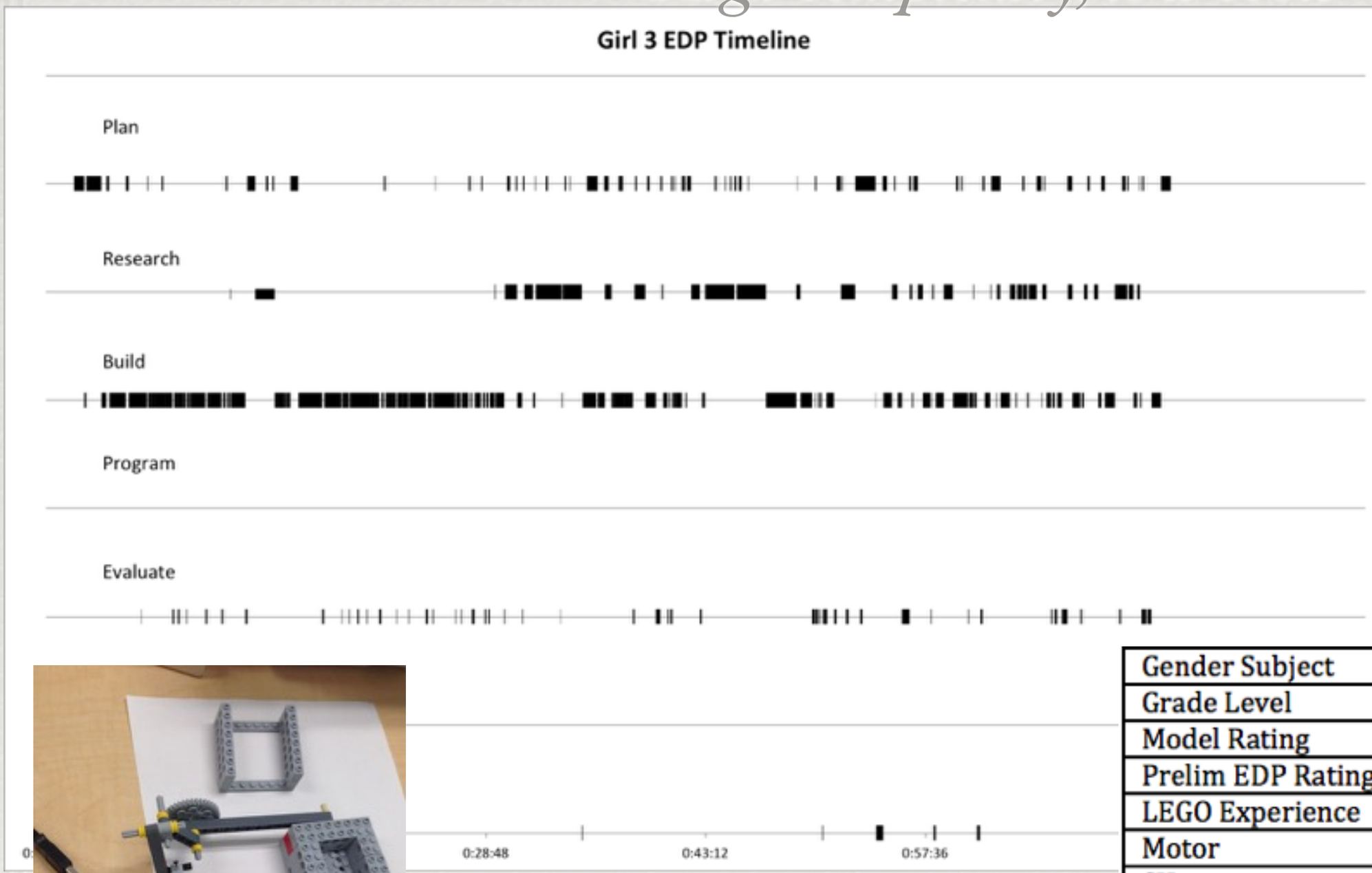


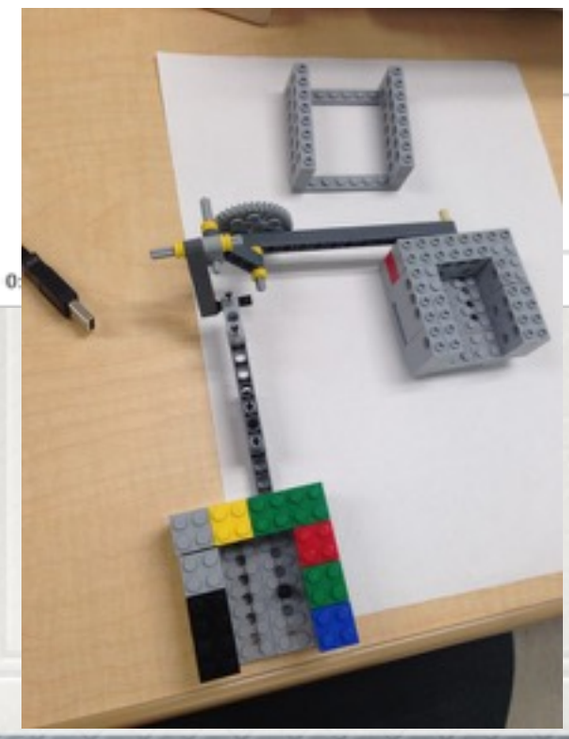
Gender Subject	Boy 8
Grade Level	2
Model Rating	2.3
Prelim EDP Rating	3
LEGO Experience	0
Motor	1
SK	Low
Math/Science	High
Design Principles	Low
EDP Process	High
CR	Low
Plan-Ahead	High
CF	Low



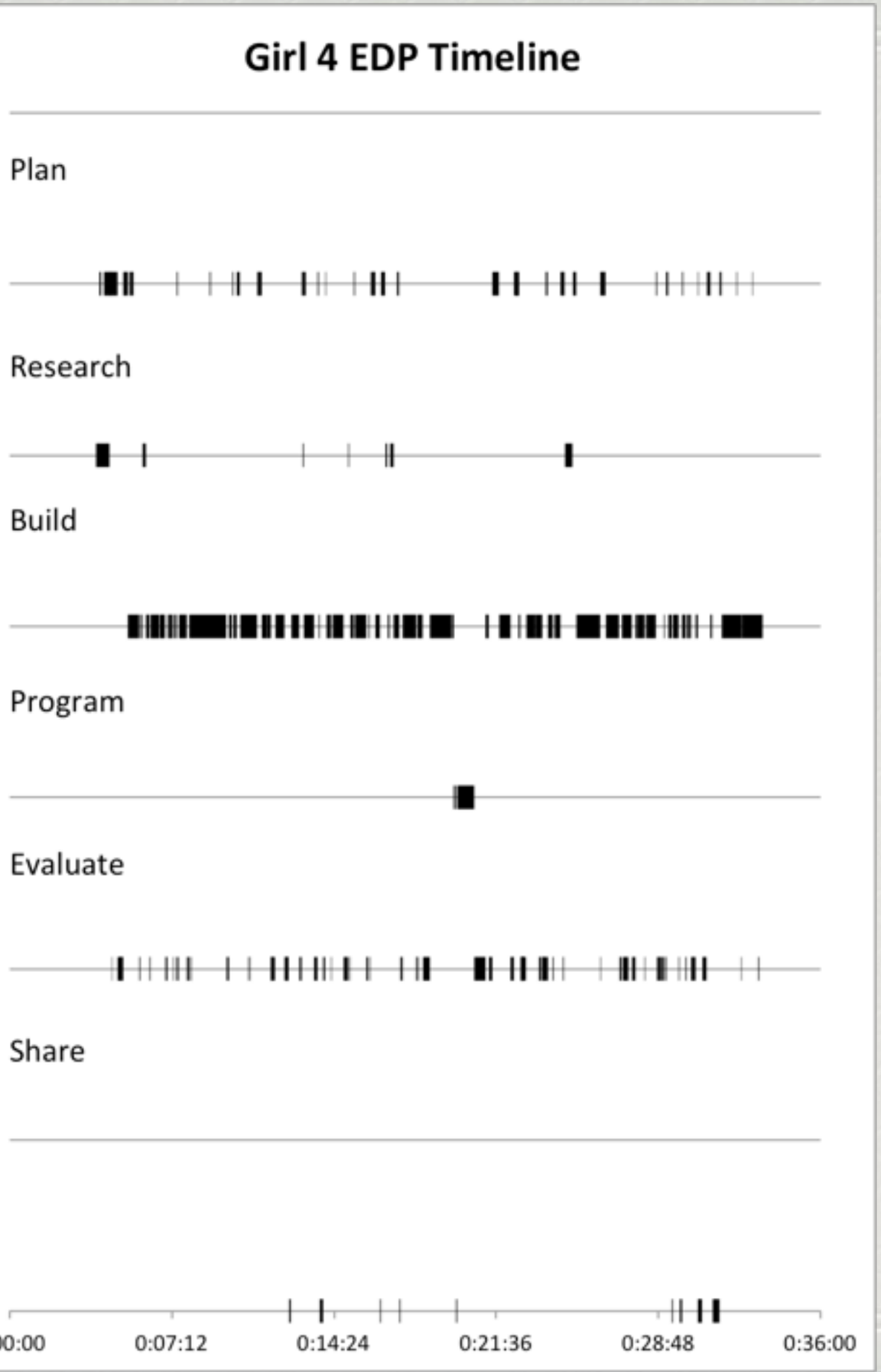
Tools a mix of high and low, close to medium overall

High complexity, low tools





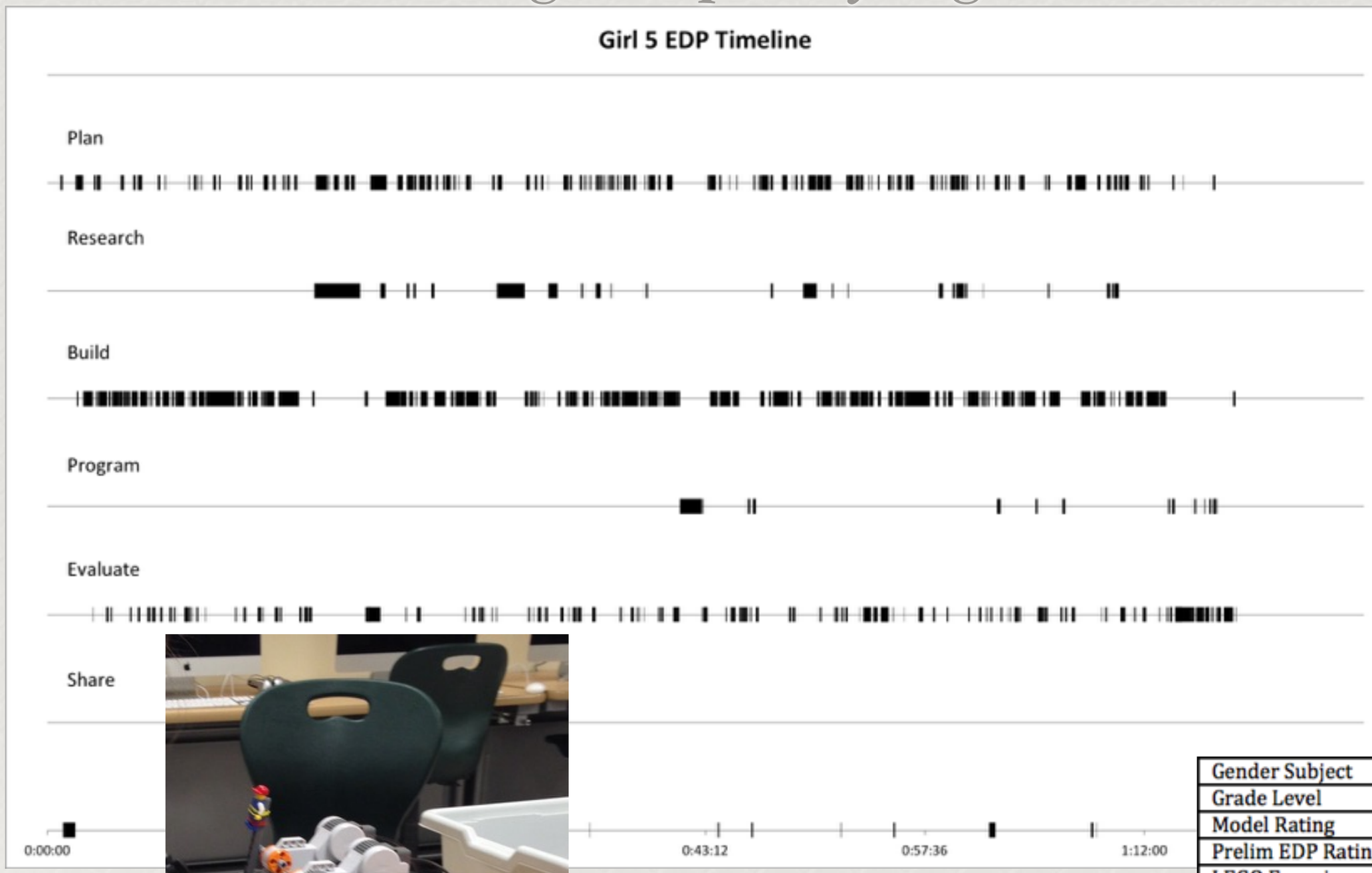
Gender Subject	Girl 3
Grade Level	6
Model Rating	1.3
Prelim EDP Rating	2
LEGO Experience	0
Motor	1 (Intended)
SK	Low
Math/Science	Low
Design Principles	Low
EDP Process	Medium
CR	Low
Plan-Ahead	Low
CF	Low

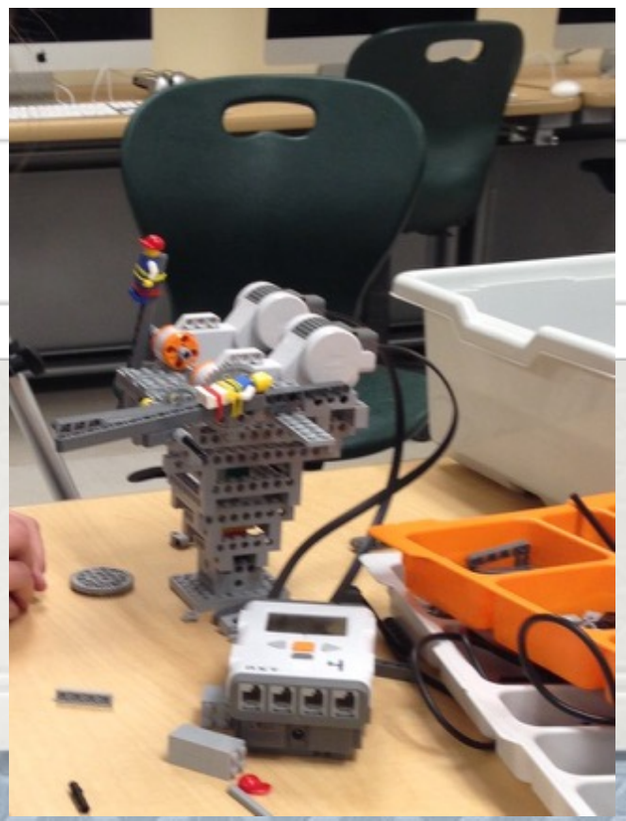


Medium complexity, medium tools

Gender Subject	Girl 4
Grade Level	6
Model Rating	2.7
Prelim EDP Rating	2
LEGO Experience	0
Motor	1
SK	Low
Math/Science	Low
Design Principles	Medium
EDP Process	Medium
CR	High
Plan-Ahead	Medium
CF	Medium

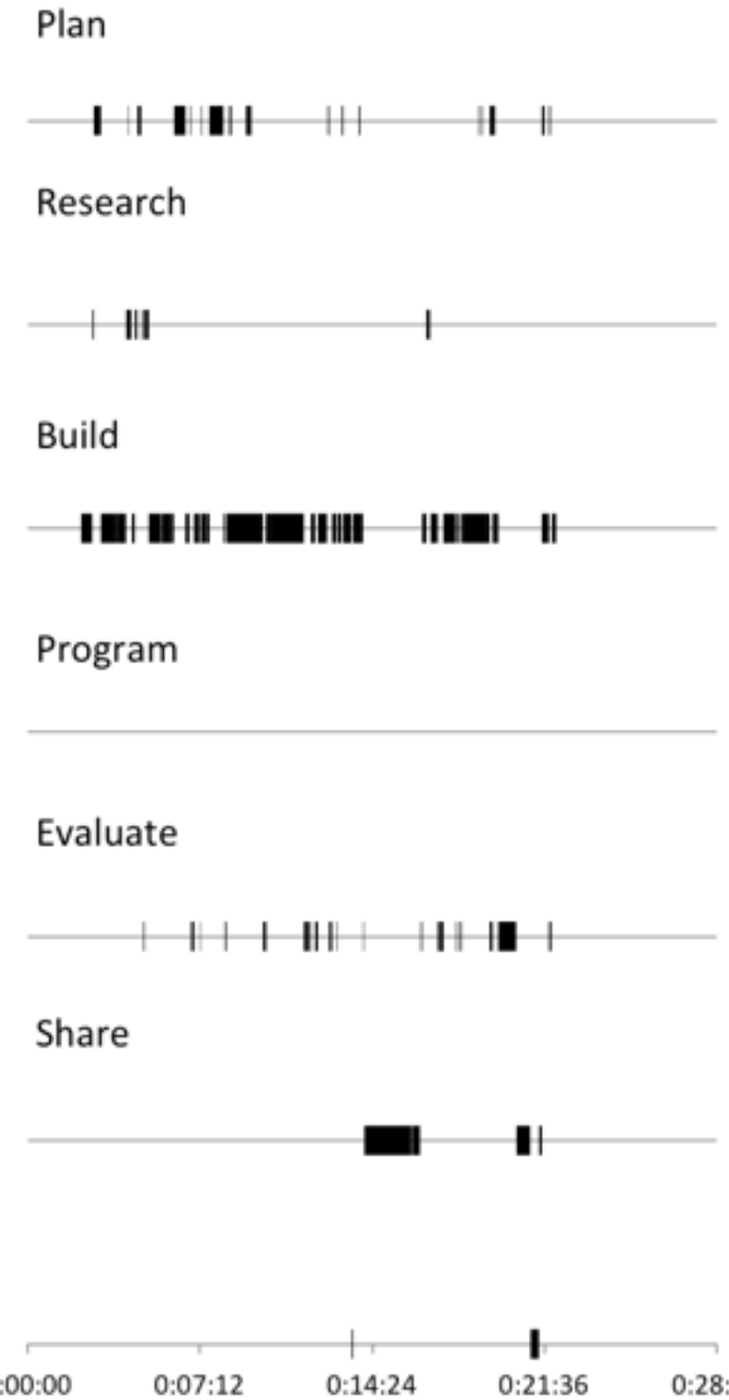
High complexity, high tools



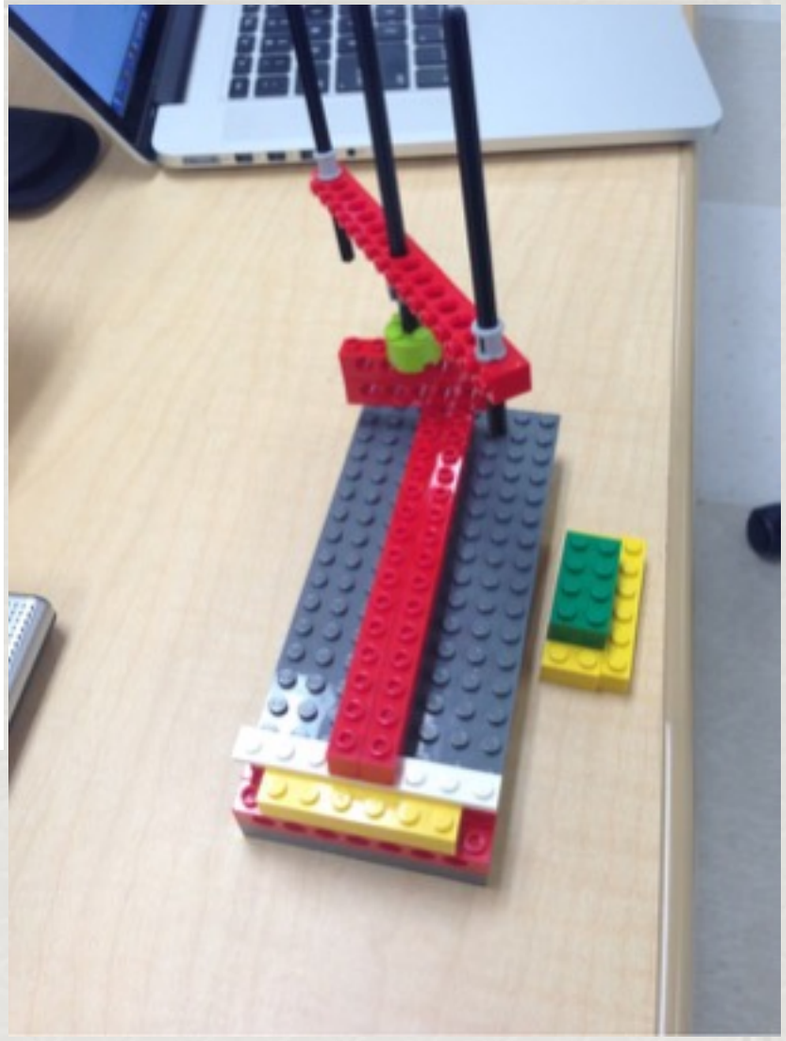


Gender Subject	Girl 5
Grade Level	6
Model Rating	3.7
Prelim EDP Rating	4
LEGO Experience	1
Motor	1
SK	High
Math/Science	High
Design Principles	High
EDP Process	High
CR	High
Plan-Ahead	High
CF	High

Girl 6 EDP Timeline



Gender Subject	Girl 6
Grade Level	2
Model Rating	2.0
Prelim EDP Rating	3
LEGO Experience	0
Motor	0
SK	Low
Math/Science	Low
Design Principles	Medium
EDP Process	Medium
CR	Low
Plan-Ahead	Low
CF	Medium



Low complexity, low tools

Girl 8 EDP Timeline

Plan

Research

Build

Program

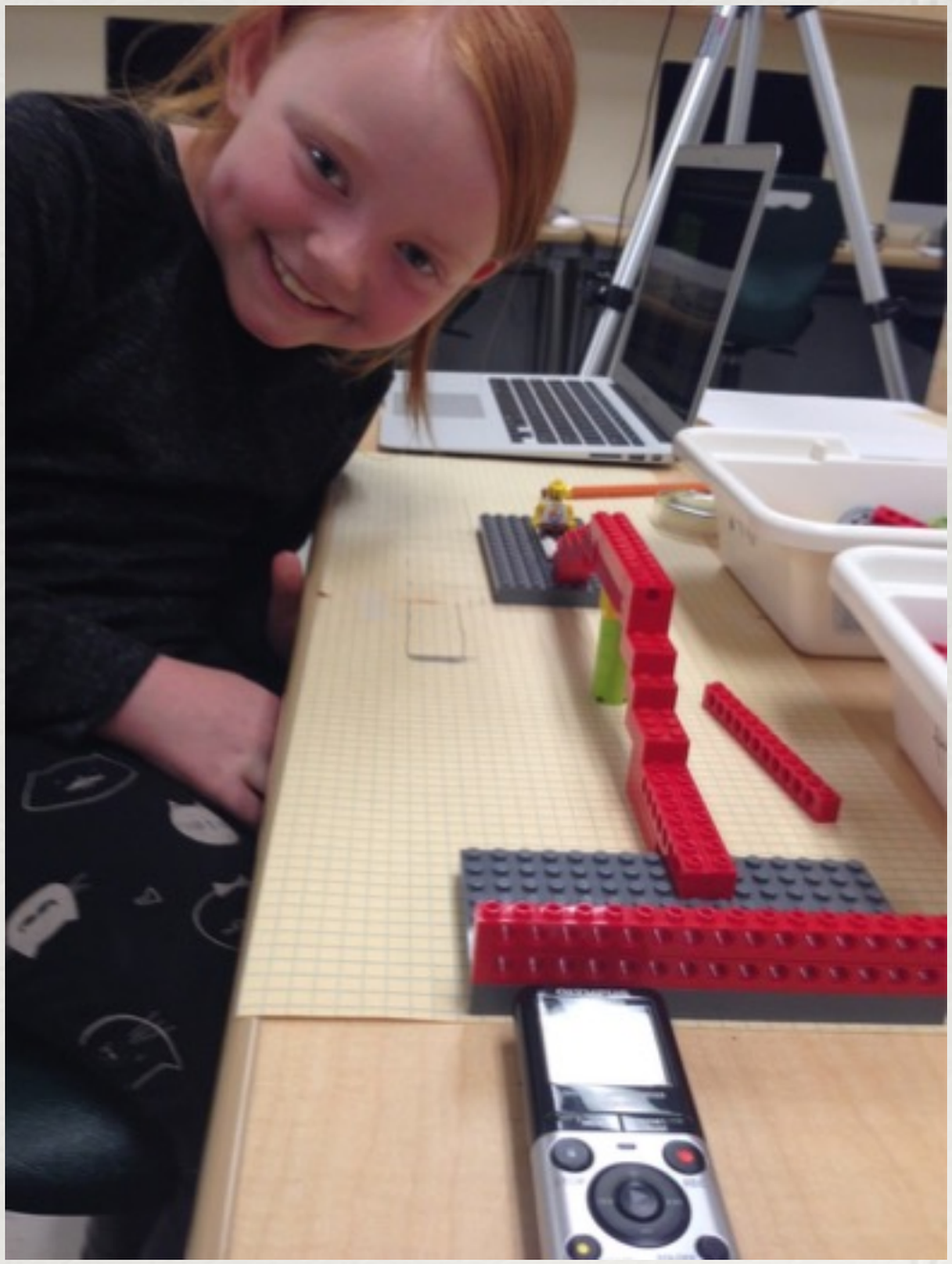
Evaluate

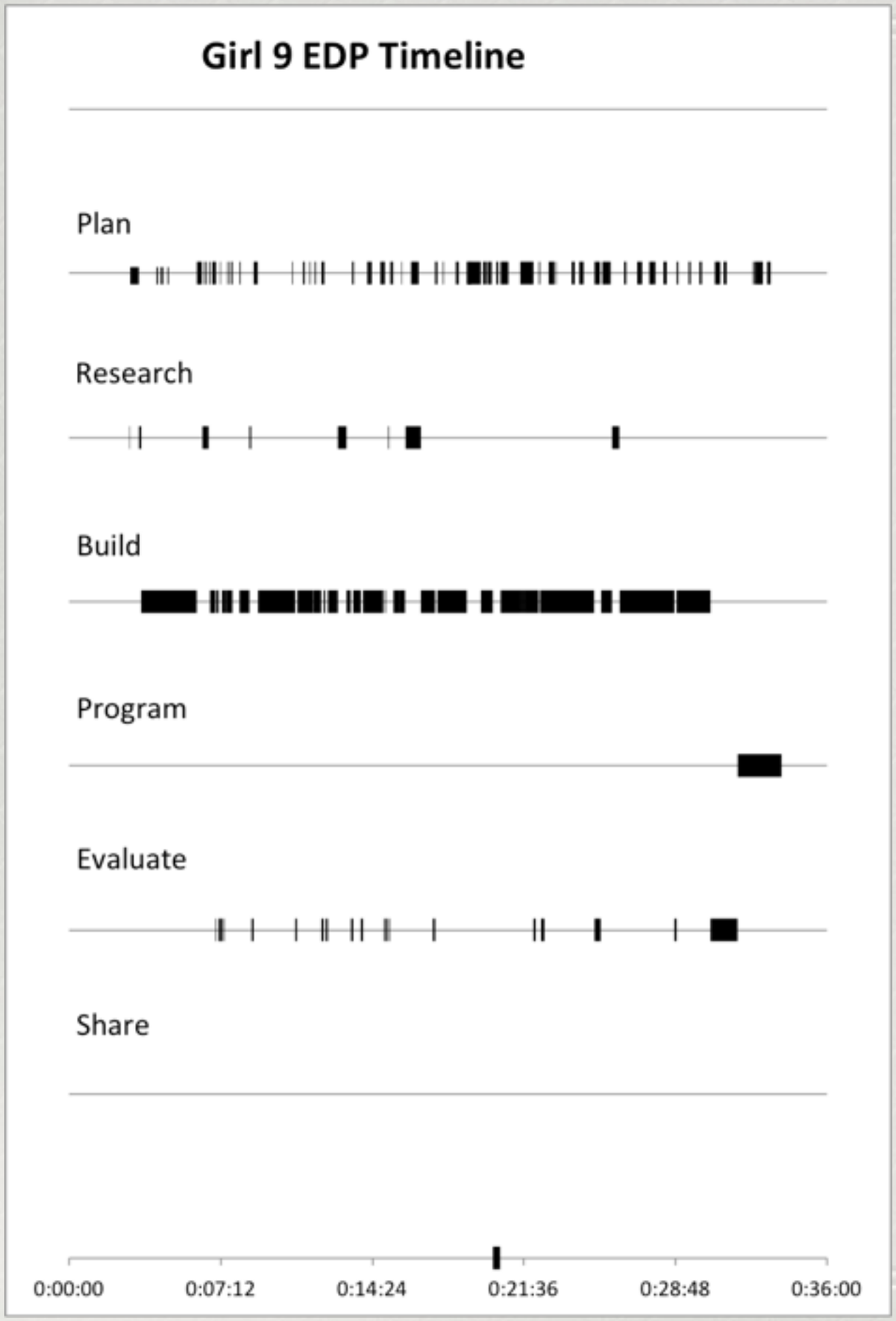
Share

0:00:00 0:07:12 0:14:24 0:21:36

Low complexity, high tools

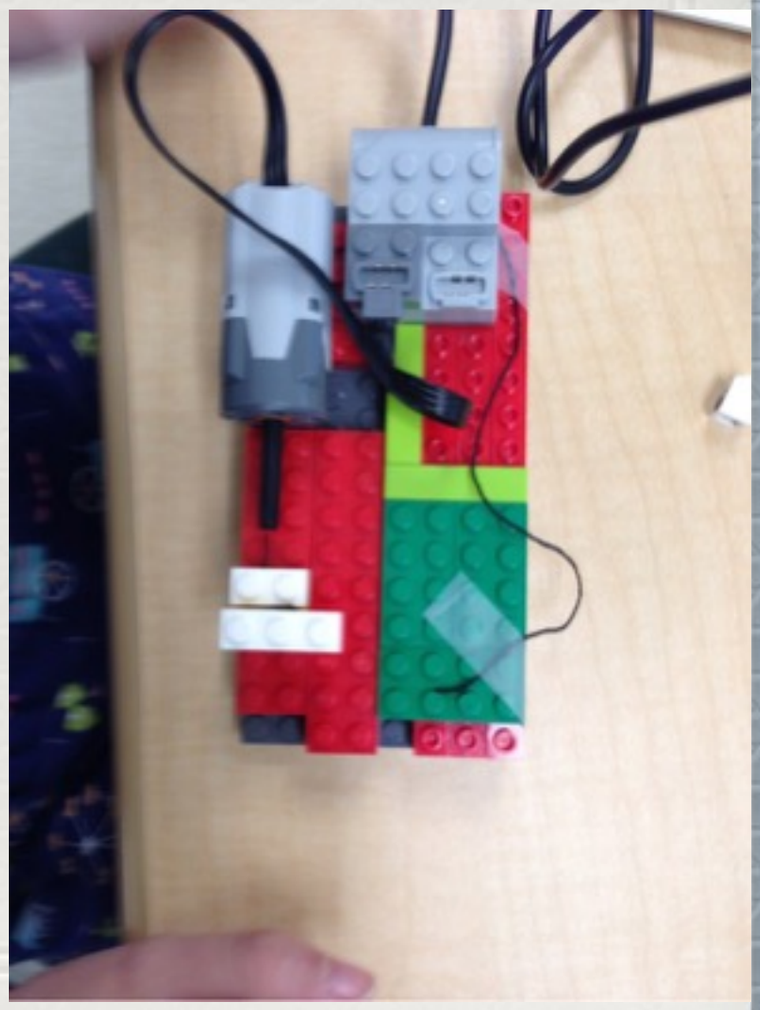
Gender Subject	Girl 8
Grade Level	2
Model Rating	3.3
Prelim EDP Rating	4
LEGO Experience	0
Motor	0
SK	High
Math/Science	High
Design Principles	High
EDP Process	High
CR	High
Plan-Ahead	High
CF	Medium





Gender Subject	Girl 9
Grade Level	2
Model Rating	2.3
Prelim EDP Rating	2
LEGO Experience	0
Motor	1
SK	Low
Math/Science	Medium
Design Principles	Medium
EDP Process	Low
CR	Medium
Plan-Ahead	Low
CF	Medium

Medium complexity, medium tools



Subject	Structural Knowledge	Math/ Science	Design Principles	EDP Process	CR	Planning	CF	Overall Knowledge and Process Rating (Tools)	Build Complexity
Boy 06	Medium	Low	Low	High	High	Low	High	Medium	High
Boy 07	Medium	Low	Medium	Medium	Medium	Low	Low	Medium	Medium
Boy 08	Low	High	Low	High	Low	High	Low	Low*	Medium
Girl 06	Low	Low	Medium	Medium	Low	Low	Medium	Low	Low
Girl 08	High	High	High	High	High	High	Medium	High	Low
Girl 09	Low	Medium	Medium	Low	Medium	Low	Medium	Medium	Medium
Boy 03	Low	Low	Low	Low	Medium	Low	Medium	Low	Low
Boy 04	High	Medium	High	Medium	High	Low	Medium	Medium	Low
Boy 05	High	Medium	High	Medium	High	High	Medium	High	High
Girl 03	Low	Low	Low	Medium	Low	Low	Low	Low	High
Girl 04	Low	Low	Medium	Medium	High	Medium	Medium	Medium	Medium
Girl 05	High	High	High	High	High	High	High	High	High

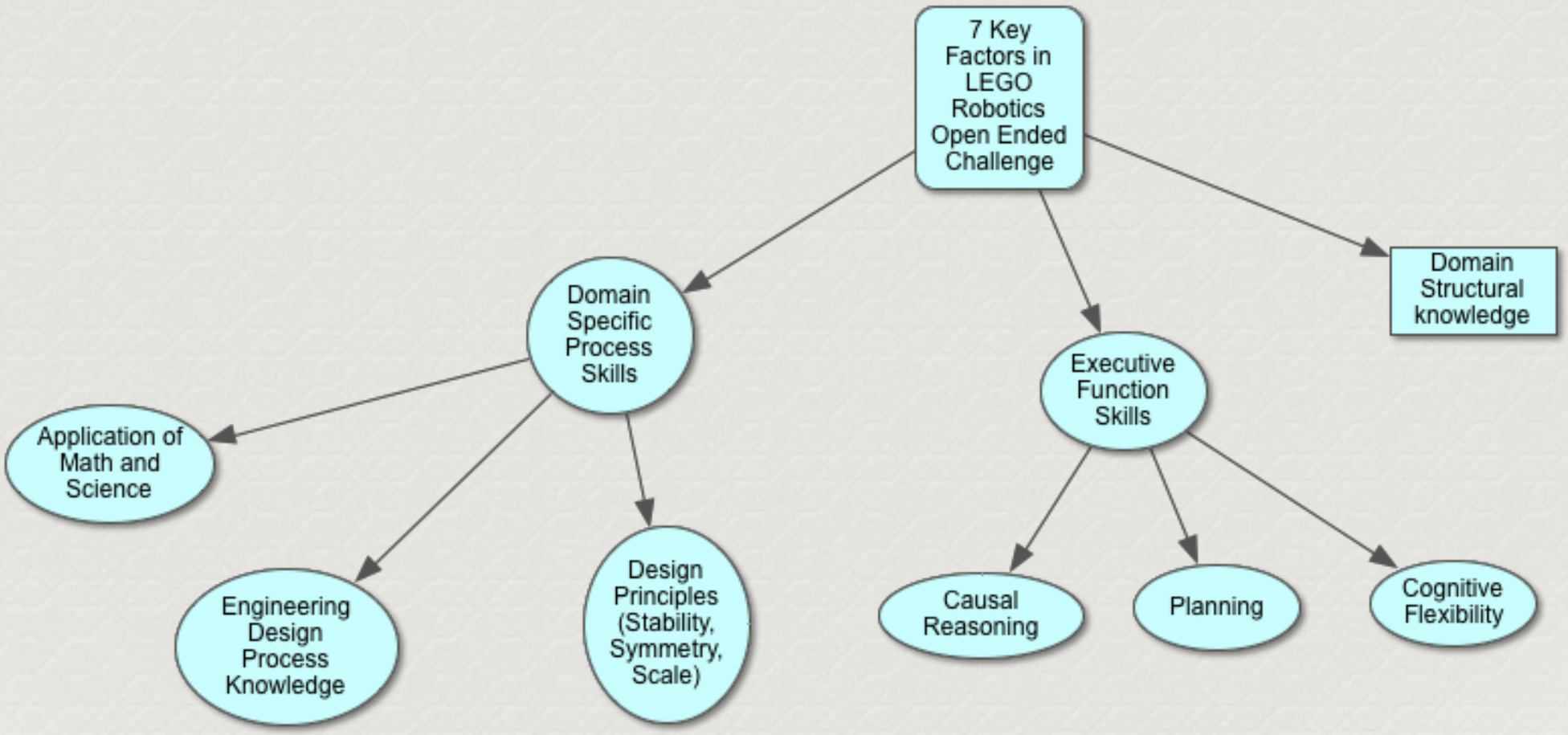
Complexity / Tools	Low	Medium	High
Low	Boy 3, Girl 6	Boy 8	Girl 3
Medium	Boy 4	Girl 4, Boy 7, Girl 9, Boy 6	
High	Girl 8		Girl 5, Boy 5

Look at graphs especially outliers:

- *Girl 5, Boy 5 - dense, mix of phases throughout*
- *Boy 3, Girl 6 - build away!*
- *Girl 3 - DNF, ongoing research and planning, which never resolved issues, serial building did not work for her*
- *Girl 8 - "idealized" EDP - plan and build*

EDP Patterns

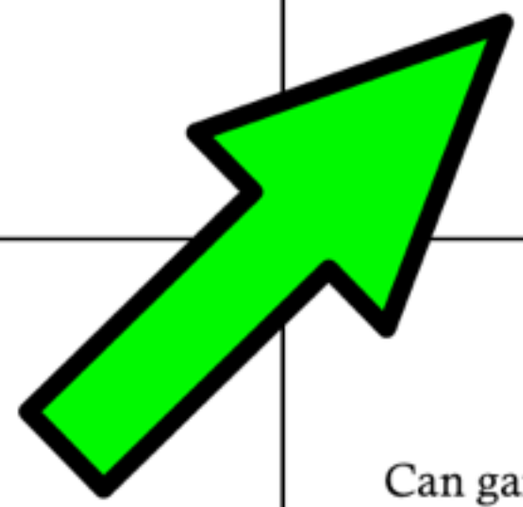
- *No clear patterns by single independent variable*
- *CR in particular may be the only direct, developmental variable in this context of age appropriate materials and instruction*
- *EDP patterns most dependent on build complexity and students tool set: structural knowledge/experience, EF, EDP process skills*


7 Key Factors in LEGO Robotics Open Ended Challenge
Domain Specific Process Skills
Application of Math and Science
Engineering Design Process Knowledge
Design Principles (Stability, Symmetry, Scale)
Domain Structural knowledge
Executive Function Skills
Causal Reasoning
Planning
Cognitive Flexibility

Structural Knowledge

Scaffold process and EF skills
May need medium complexity

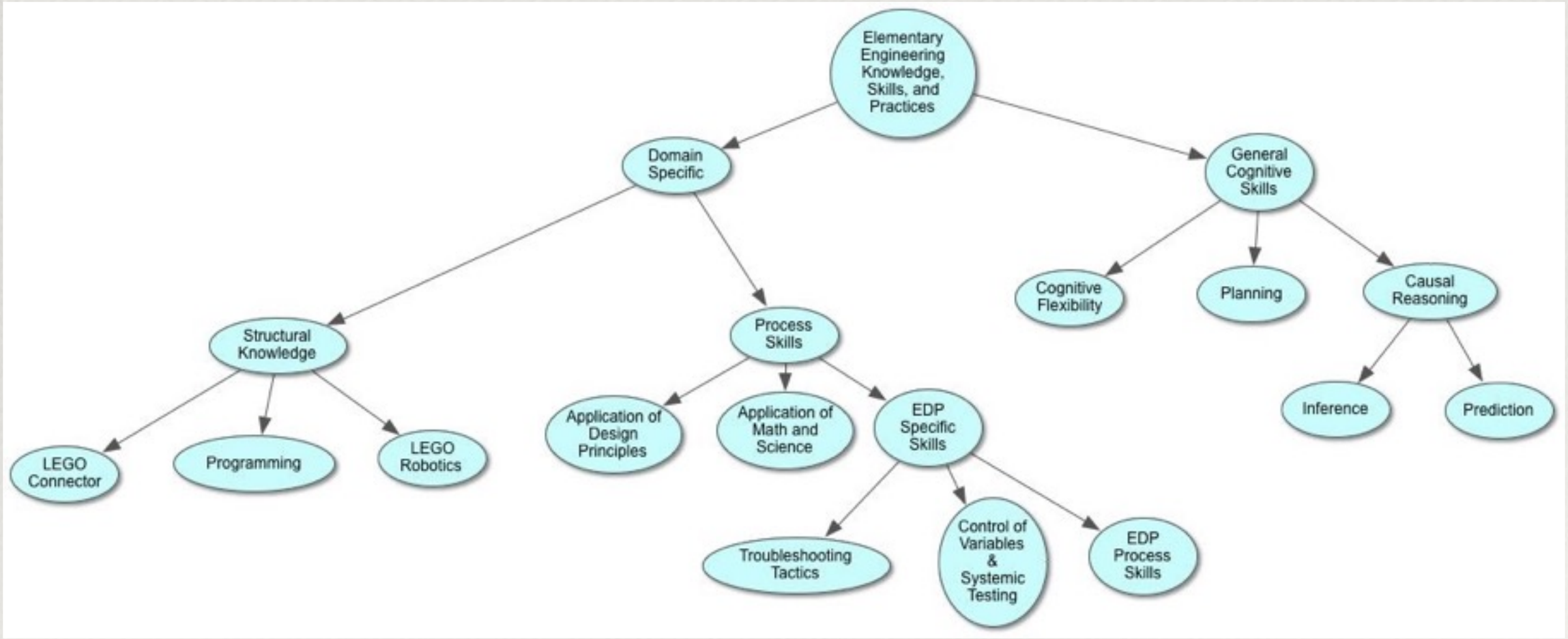
Ideal
Make sure complexity
is sufficient to challenge
Need high complexity



Teach SK and process skills
May need lower complexity,
more time, or more scaffolding
Determine general EF or domain
specific process skills or both

Can gain structural knowledge
Scaffold as needed
May need medium complexity
Determine general EF or domain
specific process skills or both

Process Skills

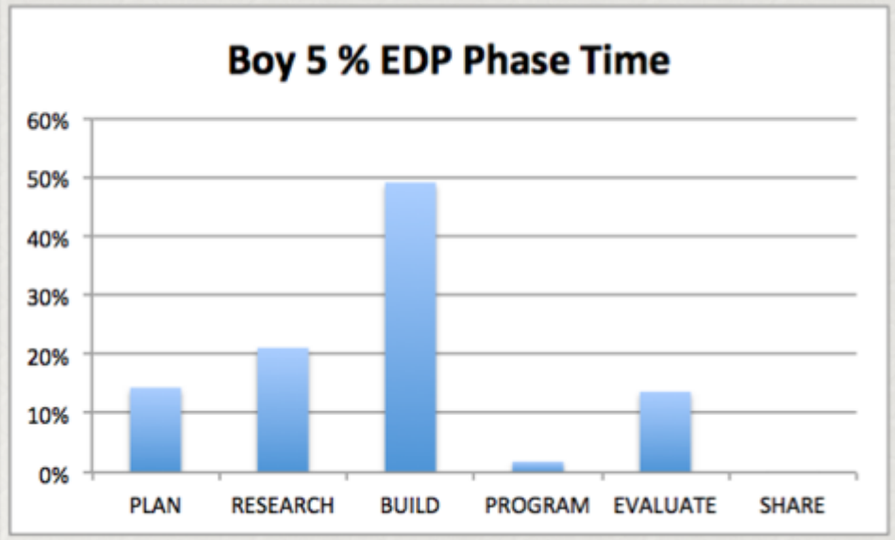

Elementary Engineering Knowledge, Skills, and Practices
Domain Specific
General Cognitive Skills
Structural Knowledge
Process Skills
Cognitive Flexibility
Planning
Causal Reasoning
LEGO Connector
Programming
LEGO Robotics
Application of Design Principles
Application of Math and Science
EDP Specific Skills
Inference
Prediction
Troubleshooting Tactics
Control of Variables & Systemic Testing
EDP Process Skills

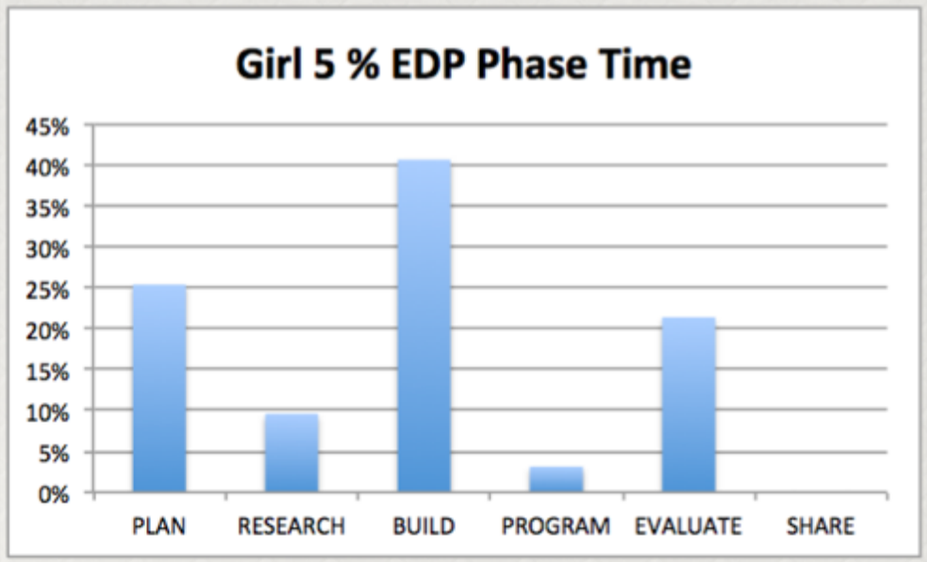
Structural Knowledge and Process Skills

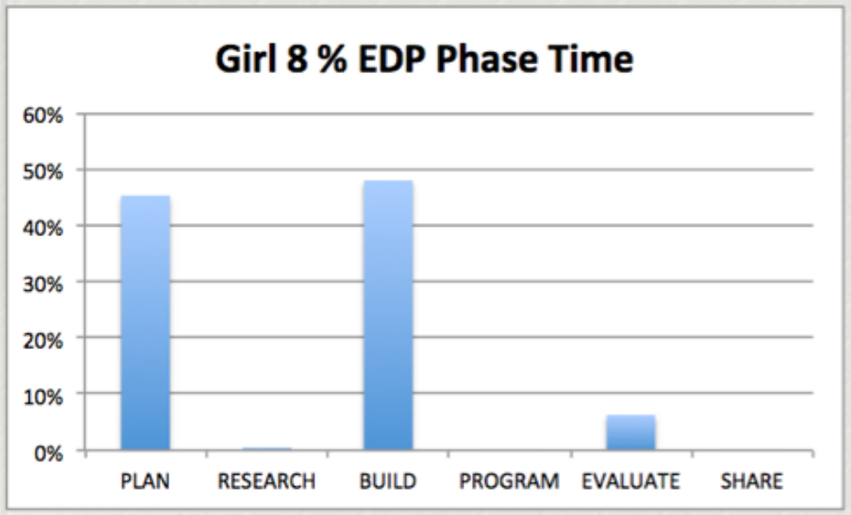
- *Domain structural knowledge (related to LEGO experience)*
- *Domain process skills*
  - *Application of math/science (can depend on domain structural knowledge)*
  - *Application of design principles (scale, symmetry, stability)*
  - *EDP (systemic testing, COV, troubleshooting tactics, EDP knowledge)*
- *Executive function*
  - *Casual Reasoning (inference, prediction, depends on structural knowledge)*
  - *Plan-ahead (system vs. serial, trial and error)*
  - *Cognitive Flexibility (or non-optimal persistence)*

Phase Data Conclusions

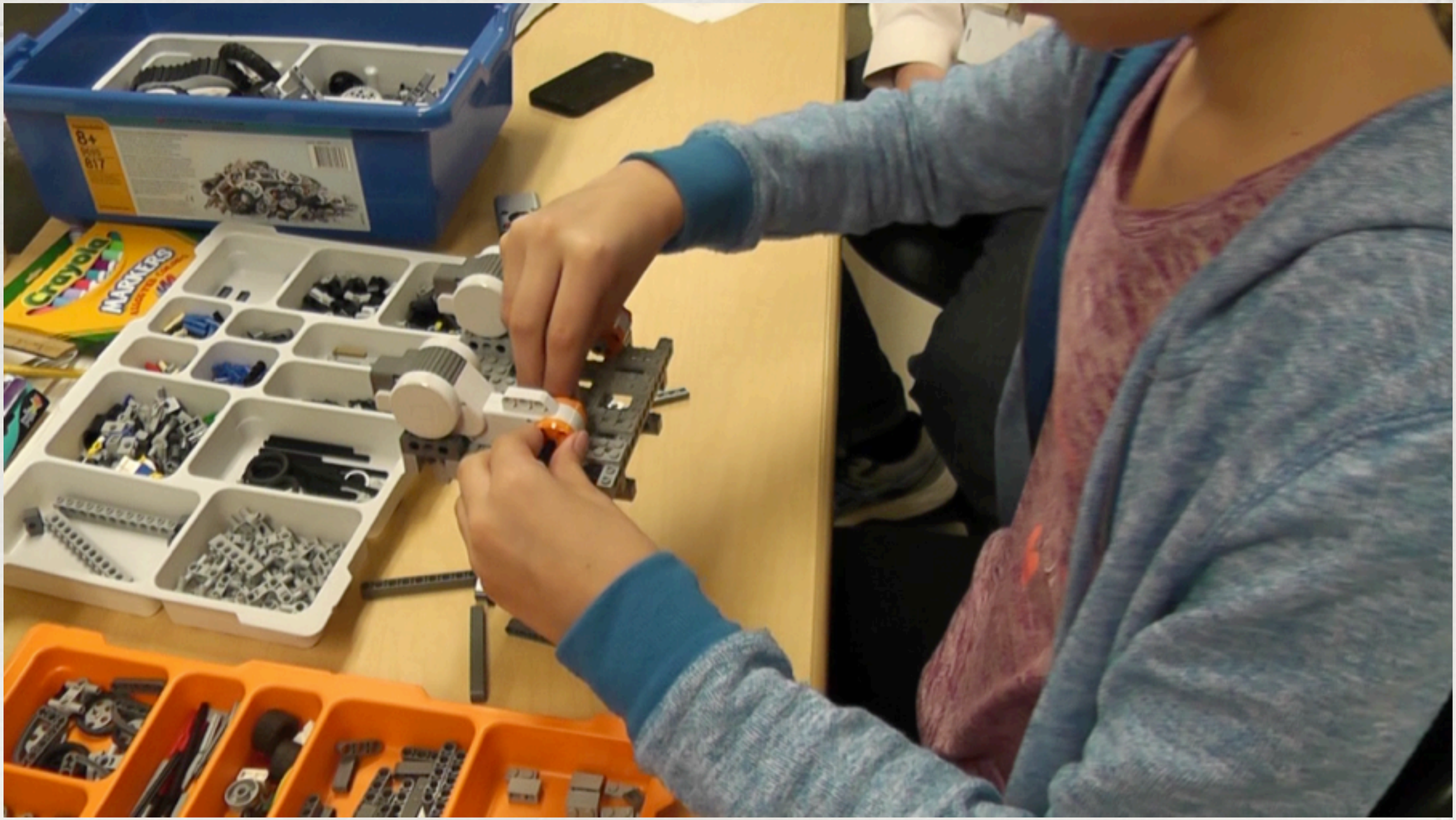
- *Total phase time most meaningful*
- *Helps tell the story of the build*
- *2 typical patterns*
- *Outlier cases*







Girl 5 Learning Moment



Boy 8 CF Example

- *Methodology*
  - *Mixing VPA and CI*
  - *VPA limitations*
- *Sample size*
- *Session time*

Future Research

- *Further analysis of subcodes and secondary codes*
- *Relative importance of different factors*
- *Segmenting data analysis*
- *Planning types - short and long term*

Resources

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

To Do

1. *Materials*
    1. *Computer, power cord, dongle*
    2. *Student builds (2) x*
    3. *D9*
    4. *Signature and title pages*
    5. *Handouts - paper x*
    6. *Handouts - post x*
    7. *Paper copies of dissertation (2x)*
    8. *Audio recorder (check batteries) x*