Elementary Robotics Pilot Study

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Research Questions

How do grade K to 6 elementary students' robotics engineering skills and processes change over time in terms of construction and programming techniques? Specifically, what changes in their techniques and processes can be seen over time that impact their ability to realize their design ideas?

Lit Review

- *Reviewed papers and books on applicable frameworks, design process models, and methodologies for a longitudinal case study of elementary robotics*

Lit Review - Frameworks

- *Constructivism (Piaget, 1969)*
  - *Map stages applicable to K-6 (preoperational, concrete operational, formal operational) to grade levels*
  - *List cognitive milestones*
- *Constructionism (Papert, 1993) basis of curriculum*
- *Social constructivism (Vygotsky, 1986),*

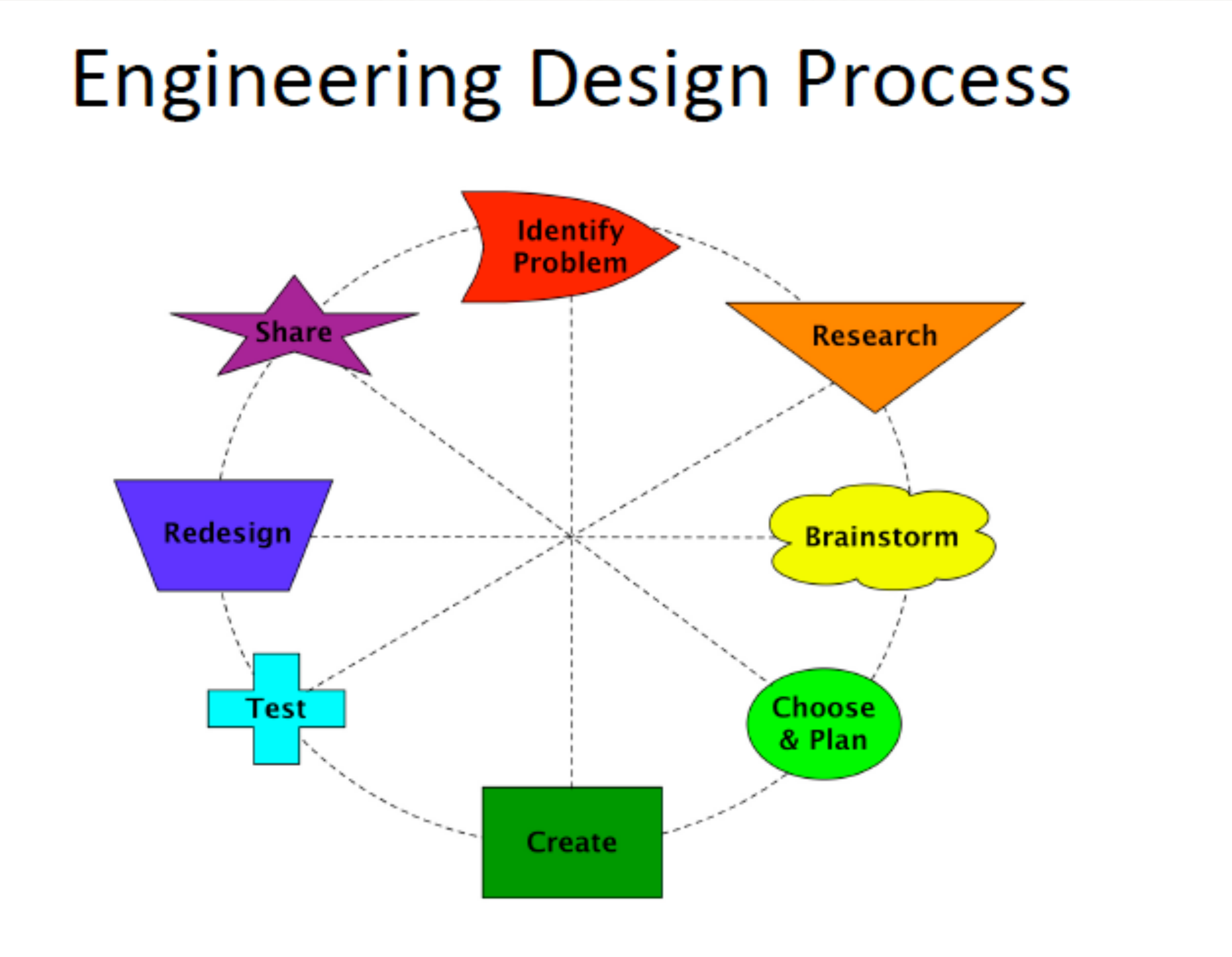
Neo-Piagetian Frameworks

- *Structures not as universal as Piaget claimed (Young, 2011)*
- *Central Conceptual Structures - (Case, 1991)*
- *Instruction/schooling part of development (Bedell & Fisher, 1992)*
- *Learning Progressions (Krajcik, 2011)*

Lit Review - Models

- *Engineering/design models (Portsmore, 2011; Crismond, 2012)*
- *Design process models are similar with different names and number of steps*
- *Design based science models include science processes*

Portsmore (2011)



Resnick (2007)

Figure 1: The kindergarten approach to learning

Bers et al (2014)

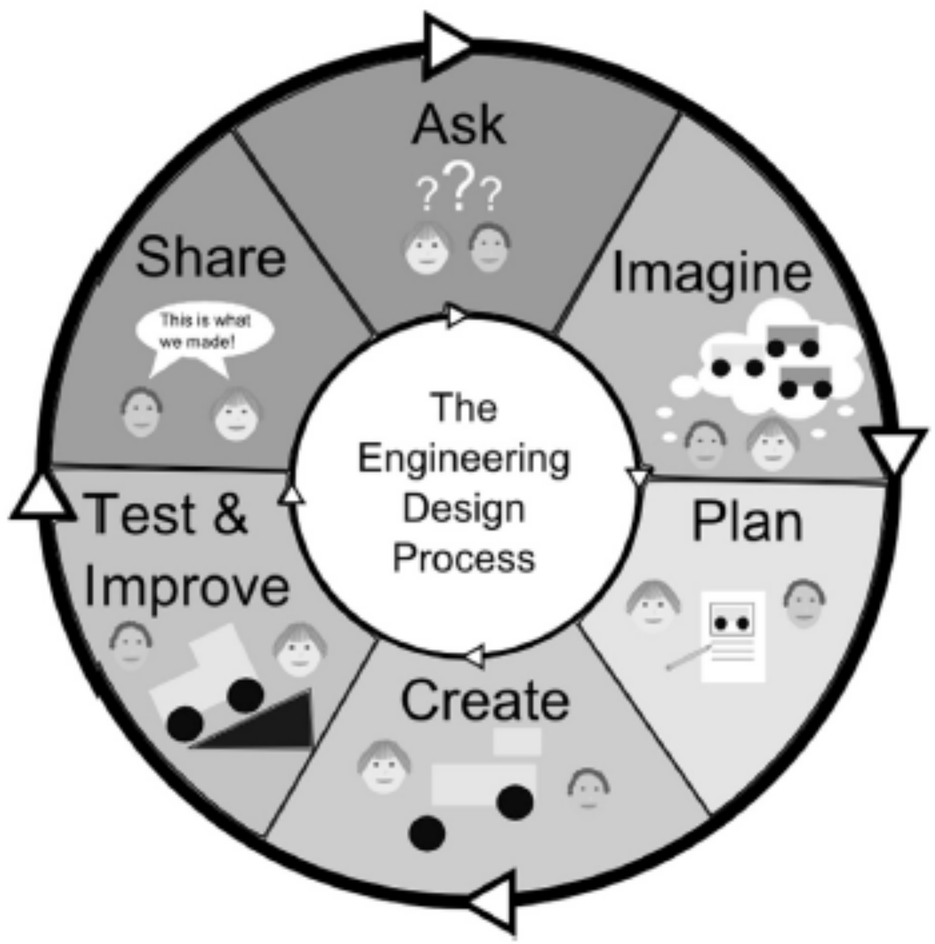


Fig. 4. An illustration of the engineering design process.

Apedoe, Reynolds, Ellefson, & Schunn (2008)

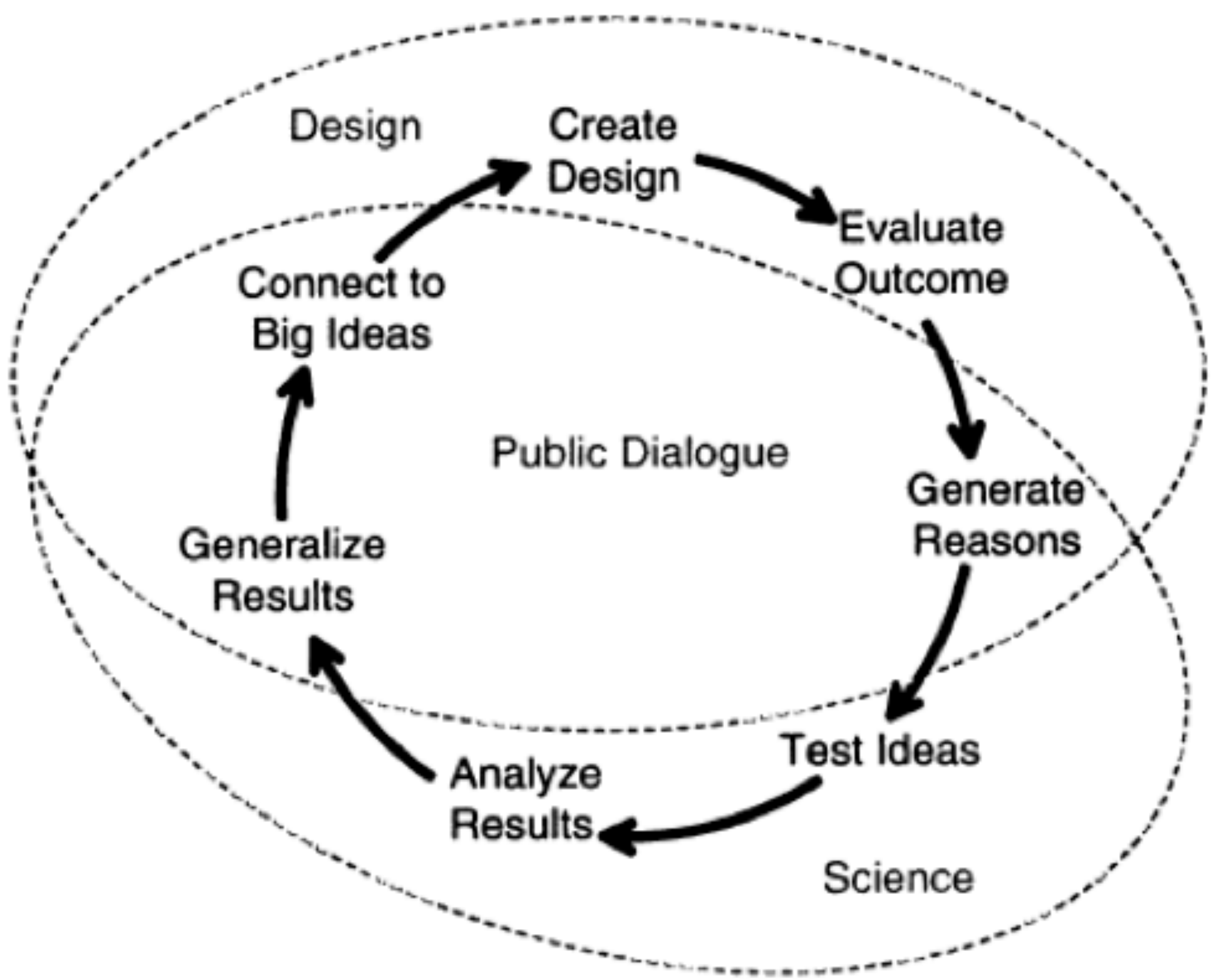


Fig. 2 Learning Cycle

Crismond & Adams (2012)

Design Strategies	Beginning vs. Informed Designer Patterns: What Beginning Designers Do	What Informed Designers Do	Learning Goals where students…	Teaching Strategies where students…
	Pattern A. Problem Solving vs. Problem Framing			
Understand the Challenge	Treat design task as a well-defined, straightforward problem that they prematurely attempt to solve.	Delay making design decisions in order to explore, comprehend and frame the problem better.	Define criteria and constraints of challenge. Delay decisions until critical elements of challenge are grasped.	State criteria and constraints from design brief in one's own words Describe how preferred design solution should function and behave Reframe understanding of problem based on investigating solutions
	Pattern B. Skipping vs. Doing Research			
Build Knowledge	Skip doing research and instead pose or build solutions immediately.	Do investigations and research to learn about the problem, how the system works, relevant cases, and prior solutions.	Enhance background knowledge, and build understandings of users, mechanisms and systems.	Do info searches/read case studies Write product history report Do studies/research on users Reverse engineer existing products Conduct product dissections
	Pattern C. Idea Scarcity vs. Idea Fluency			
Generate Ideas	Work with few or just one idea, which they can get fixated or stuck on, and may not want to change or discard.	Practice idea fluency in order to work with lots of ideas by doing divergent thinking, brainstorming, etc.	Generate range of design ideas to avoid fixation. Know guidelines/reasons for various divergent thinking approaches.	Do brainstorming and related techniques to achieve idea fluency Relax real-world constraints or alter original task to see it in new ways Do generative database searches
	Pattern D. Surface vs. Deep Drawing & Modeling			
Represent Ideas	Propose superficial ideas that do not support deep inquiry of a system, and that would not work if built.	Use multiple representations to explore and investigate design ideas and support deeper inquiry into how system works.	Explore and investigate different design ideas via sketching, modeling solutions, and making simple prototypes.	"Mess about" with given models Use words, gestures, artifacts to scaffold visualizing solutions Do rapid prototyping using simple materials or various drawing tools Conduct structured review of ideas

EDP Models - Conclusion

- *Use a variation of the standard engineering design process model that focuses on observable behavior and will get at what is challenging for the students*
- *Main EDP codes: plan, research, build, rebuild, program, reprogram, evaluate, wait*

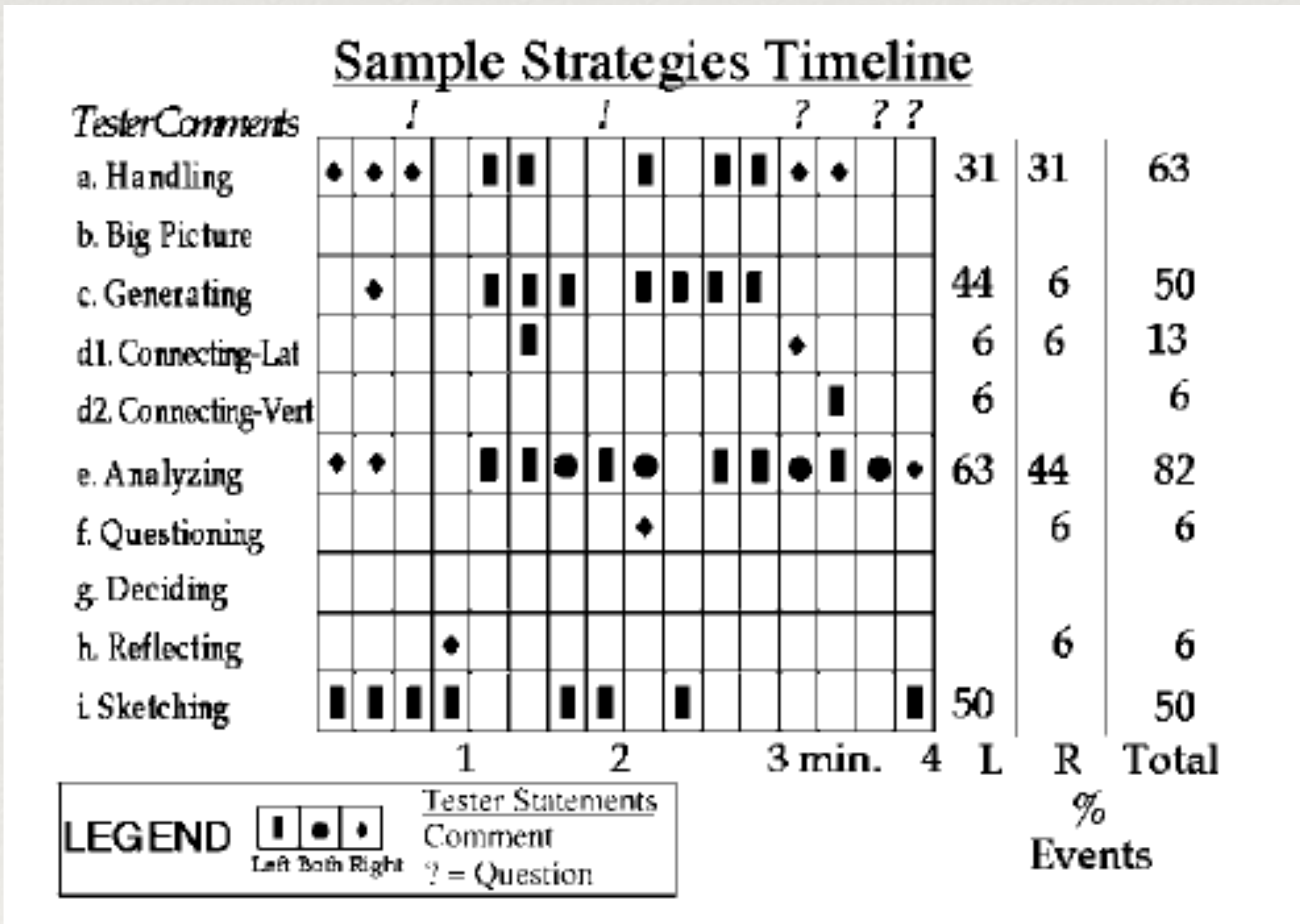
Causal Reasoning

- *Piaget - from realism, objectivity, reciprocity, relativity, from magical, self-centered to eventual scientific/ objective (Fuson, 1976)*
- *Most people are not good at causal reasoning and selectivity pick data to match their pre-existing ideas (Kuhn & Dean, 2004)*

Casual Reasoning

- *Consists of quantitative (math/data) and qualitative mechanism (science)*
- *Need both (Kuhn & Dean, 2004)*
- *Usually* a posteriori
- *In general, engineers engage in* a priori *predictions (mental projections) about the performance of designs*

Methodologies - Crismond (2001)



Welch (1999)

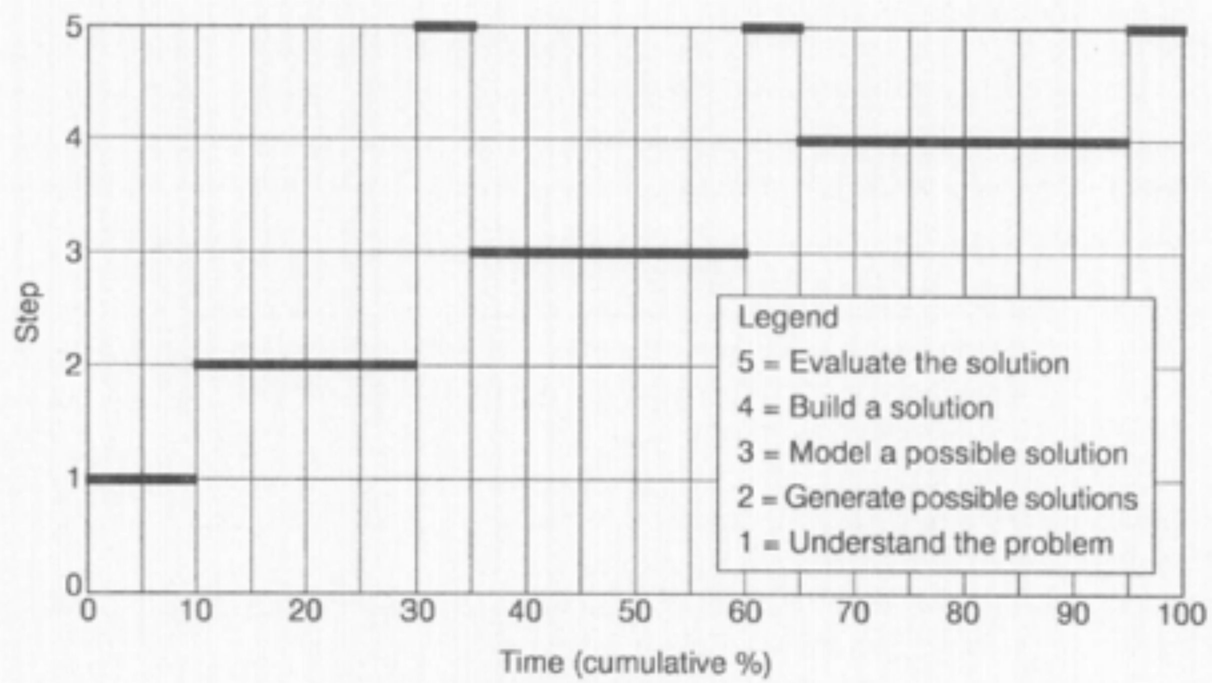


FIG. 3. Map of the five-step theoretical design process used in this study.

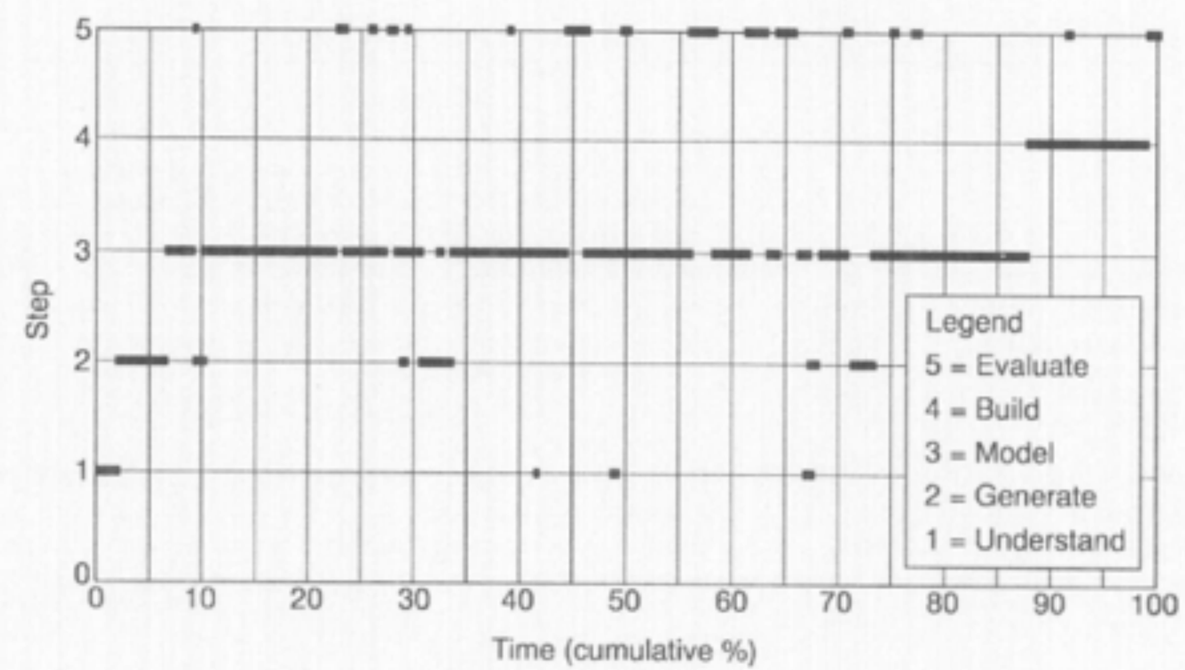
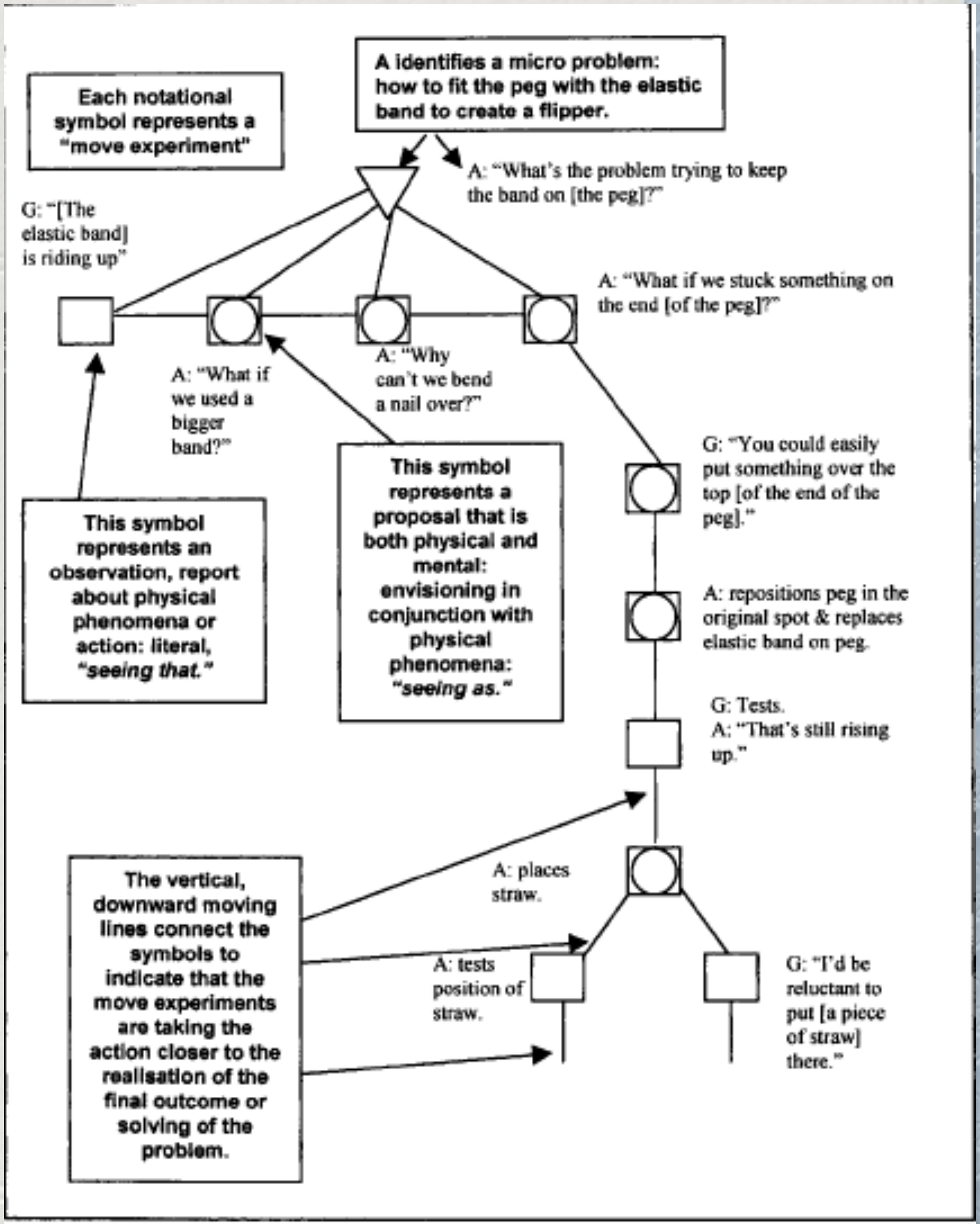


FIG. 2. The strategy used by dyad 5.

McRobbie et al (2001)



Roden (1997, 1999)

Table 1: Strategy variation over Key Stage 1

Changing Strategies	Evolving Strategies	Emergent Strategies
Negotiation and Reposing the Task	Focusing on Tasks or Materials	Practice and Planning
Sharing and Co-operating	Identifying Wants and Needs	
Showing and Evaluating	Identifying Difficulties	
	Tackling Obstacles	
Unchanging Strategies	**Declining Strategies**	
Panic and Persistence	Personalisation	
	Talking to Self	

Lit Review - Conclusions

- *No systematic longitudinal studies of children's cognitive design processes*
- *Many calls for more longitudinal studies - (Crismond, 2012; Penner et al., 1997; Roth, 1996)*

Pilot Study Goals

- *Establish task*
- *Establish methodology*
- *Establish data analysis*
- *Look for emergent themes*

Methodology

- *Qualitative, Cross Case, Longitudinal, Cross-Sectional (Yin, 2006) (Borman, Clarke, Cotner, & Lee, 2006)*
- *Semi-clinical video interview (Piaget & Inhelder, 1969)*
- *Microgenetic Analysis (Chinn, 2006; Siegler & Crowley, 1991)*
- *Film one second grade student and one grade six student doing same open-ended engineering task (Erickson, 2006)*
- *Transcribed and coded using grounded theory (Glaser & Strauss, 2009)*

Process

- *Kept process journal*
- *Process was very iterative and emergent but not infinite*

Main EDP Codes

- *Main EDP codes: plan, research, build, rebuild, program, reprogram, evaluate, wait*

Model - Sub-Codes

- *Plan, Research, Build-Normal, Build-Rebuild, Program-Normal, Program-Reprogram, Evaluate-Physical, Evaluate-Verbal, Evaluate-System, Evaluate-Visual, Wait*

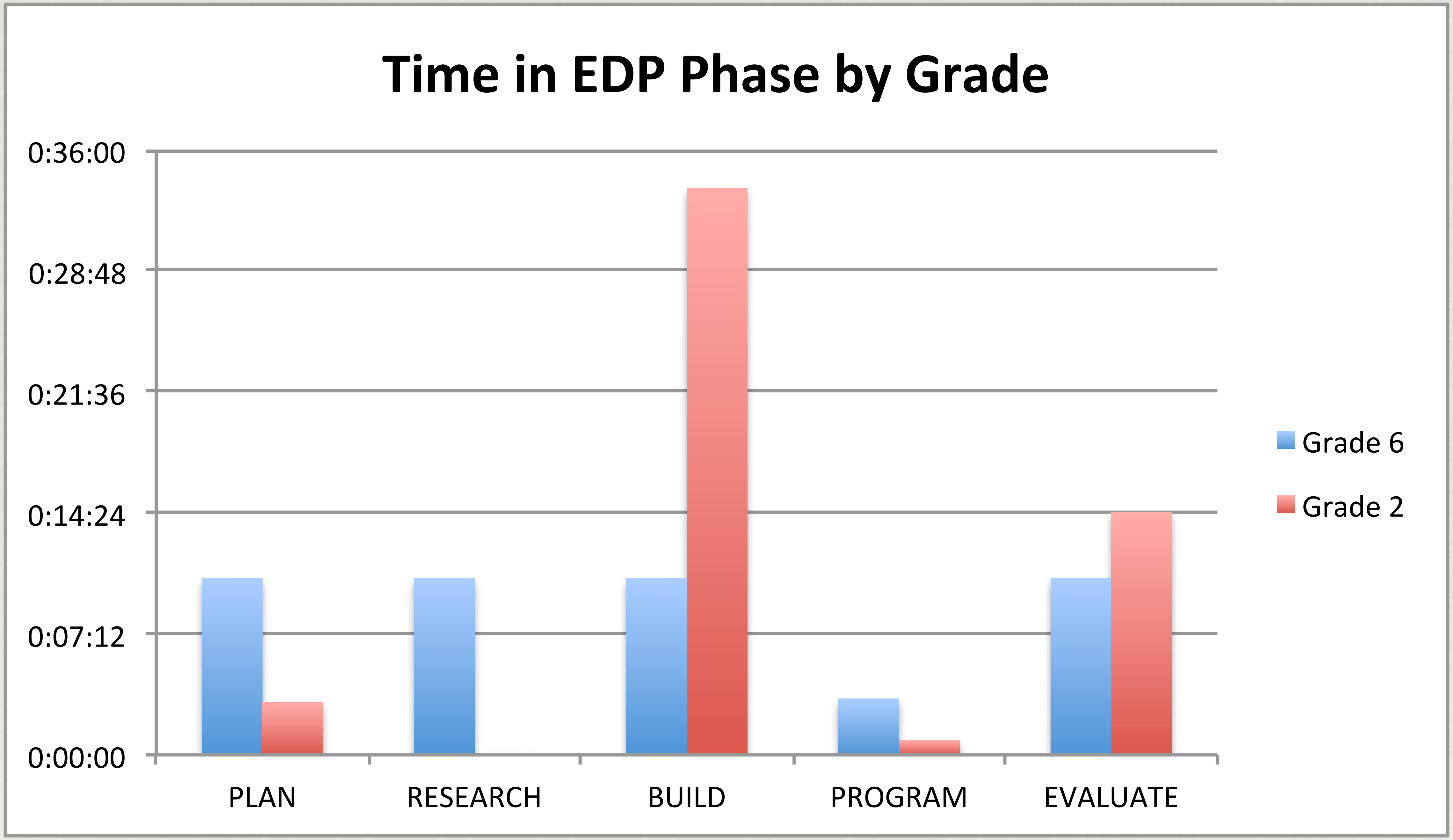
Emergent Non-EDP Codes

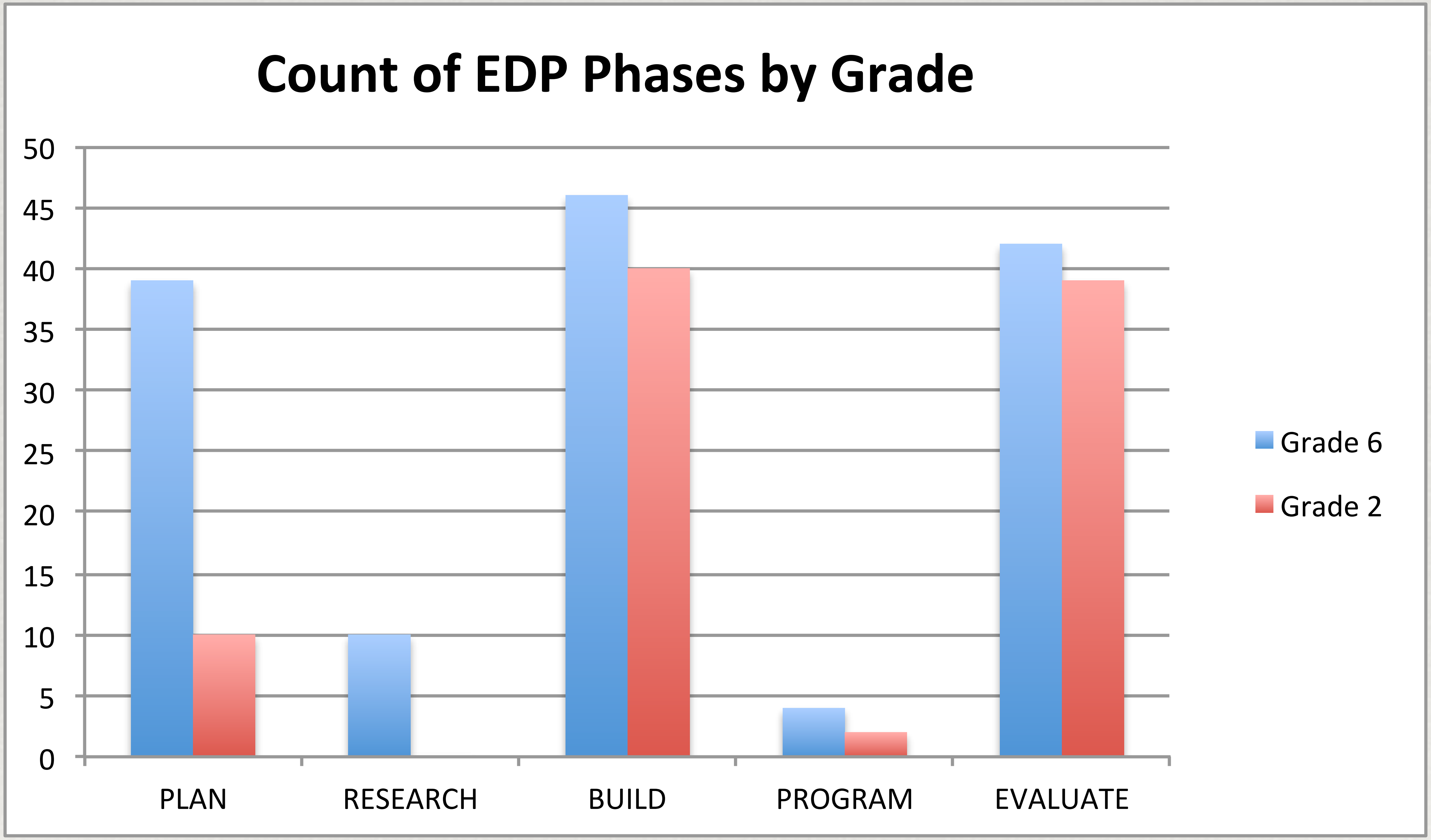
ASYMMETRY, SYMMETRY, STABILITY, PROBLEM-SOLVING, SCALE, CONNECTION, MATH,SCIENCE, SEQUENCING, SYSTEMS-THINKING, FINE-MOTOR,

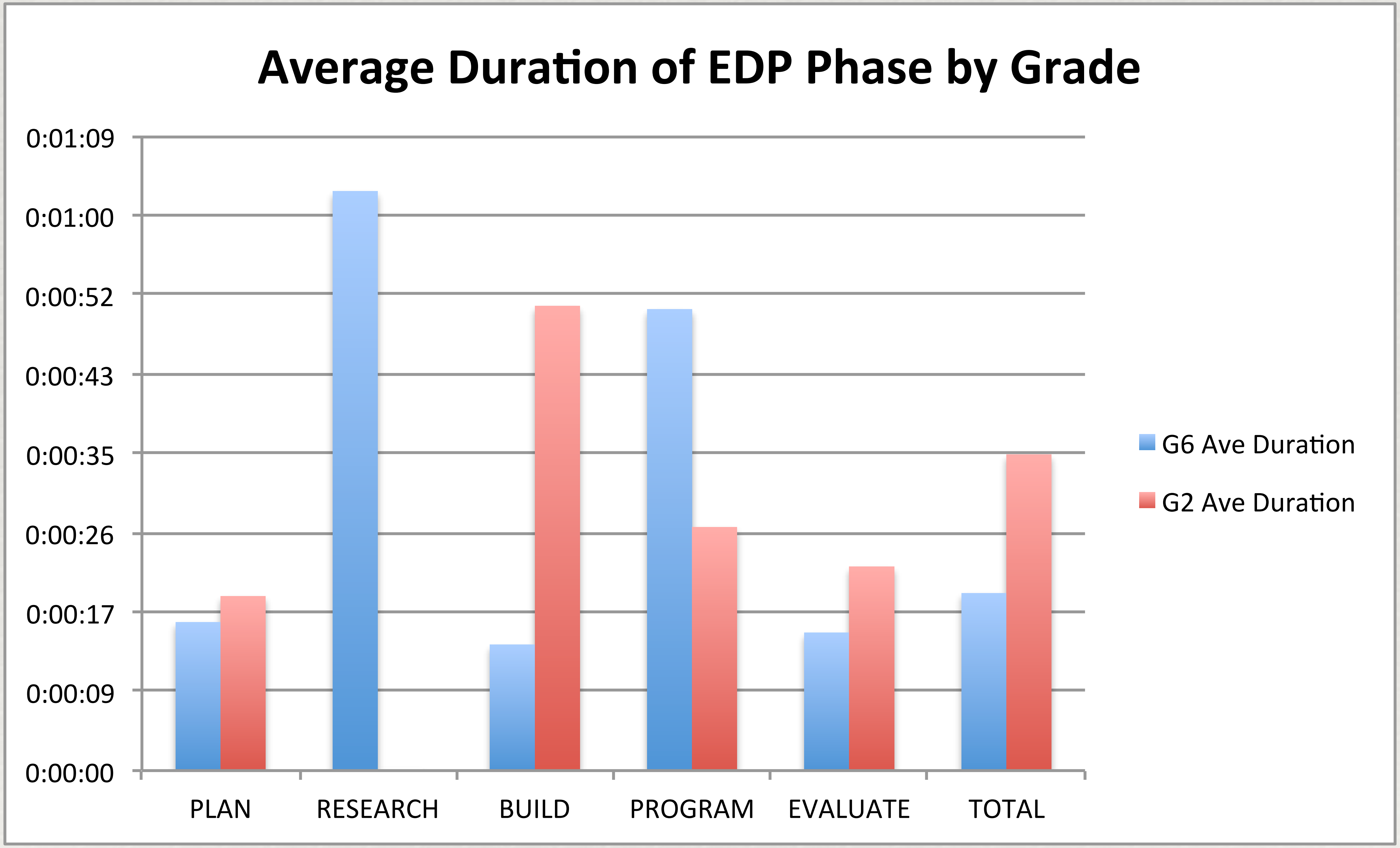
PROJECT-CORRECT, PROJECT-INCORRECT, SEMI-CONCRETE, UNANTICIPATED-CONSEQUENCE,PERSIST-BAD

AFFECT, TALK-TO-ROBOT, CREATIVE-PLAY, SELF-TALK,

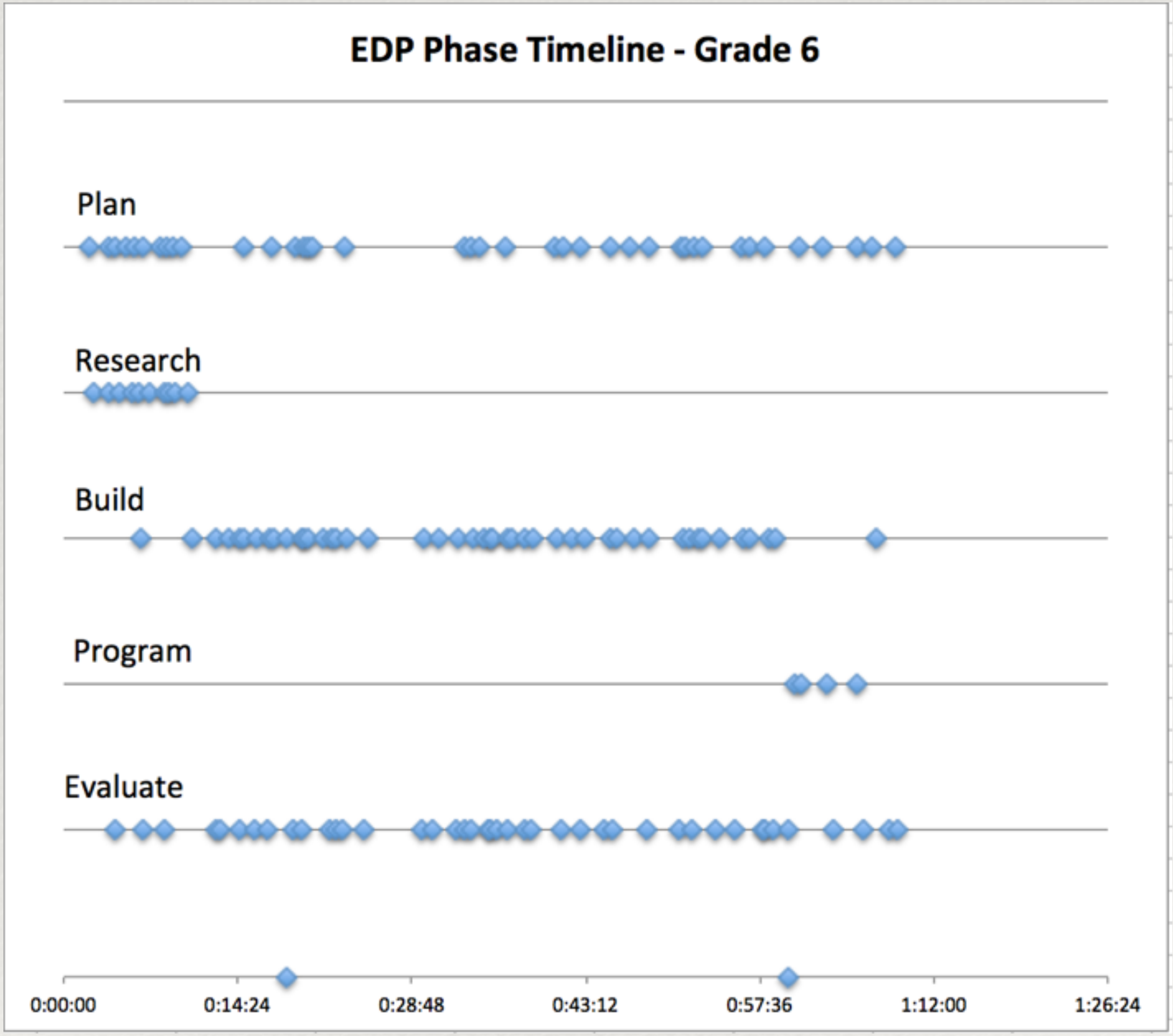
MULTIPLE-PHASES, TALK-ALOUD-ARTIFACT, STRATEGY, IMPORTANT


Time in EDP Phase by Grade
0:36:00
0:28:48
0:21:36
0:14:24
0:07:12
0:00:00
PLAN
RESEARCH
BUILD
PROGRAM
EVALUATE
Grade 6
Grade 2

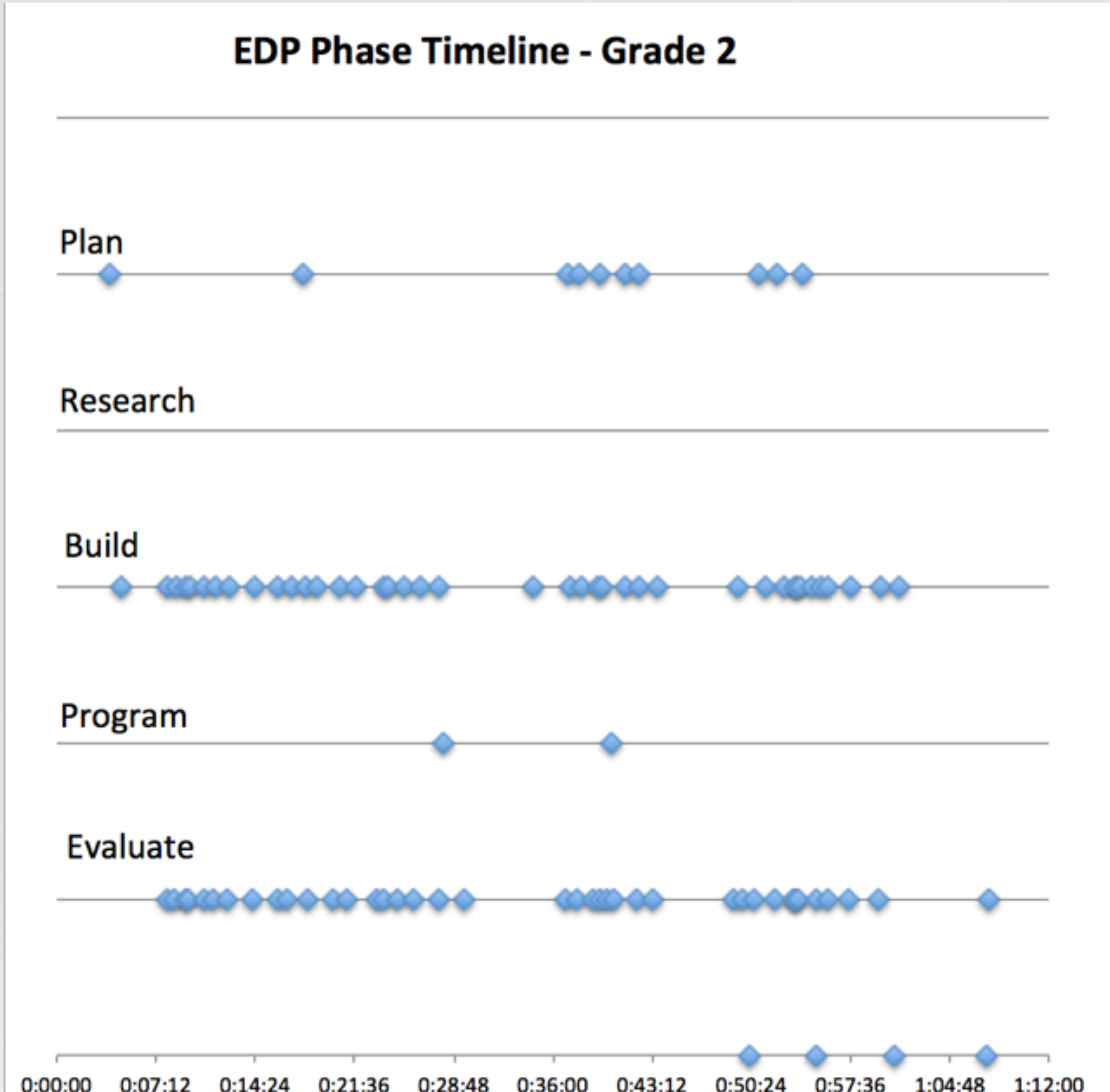

Count of EDP Phases by Grade
50
45
40
35
30
25
20
15
10
5
0
PLAN
RESEARCH
BUILD
PROGRAM
EVALUATE
Grade 6
Grade 2

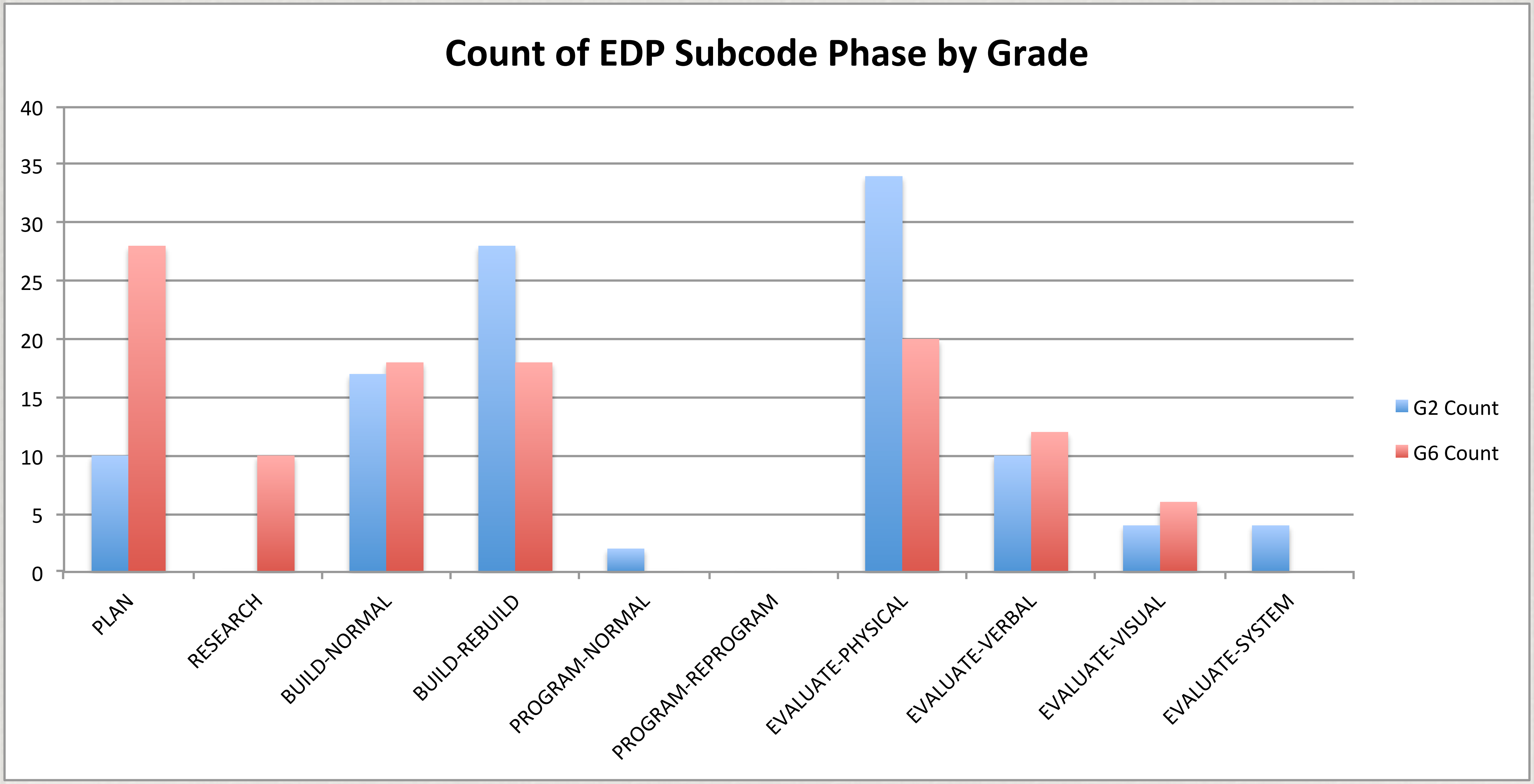


Average Duration of EDP Phase by Grade
0:01:09
0:01:00
0:00:52
0:00:43
0:00:35
0:00:26
0:00:17
0:00:09
0:00:00
PLAN
RESEARCH
BUILD
PROGRAM
EVALUATE
TOTAL
G6 Ave Duration
G2 Ave Duration



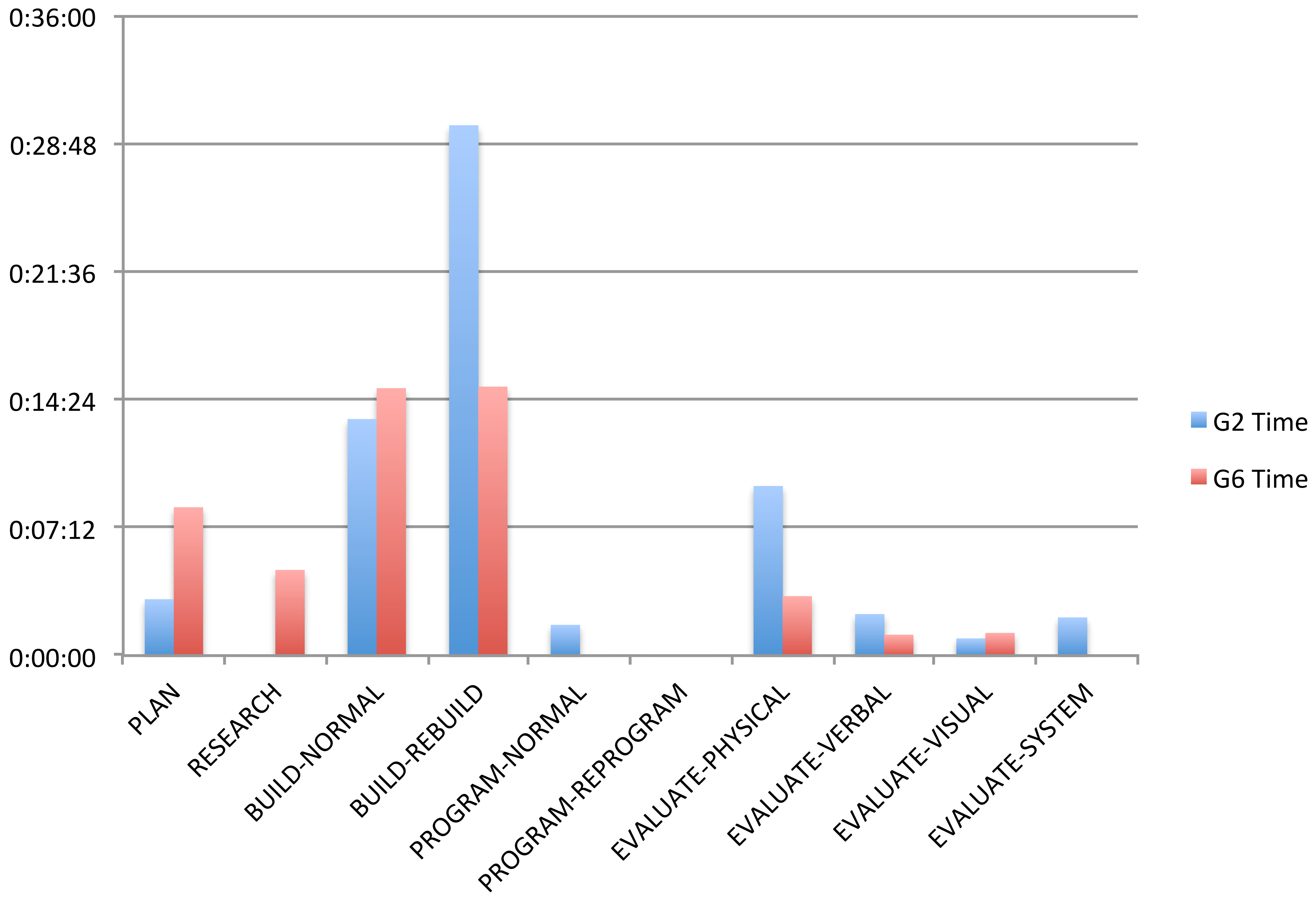
EDP Phase Timeline - Grade 6
Plan
Research
Build
Program
Evaluate
0:00:00
0:14:24
0:28:48
0:43:12
0:57:36
1:12:00
1:26:24

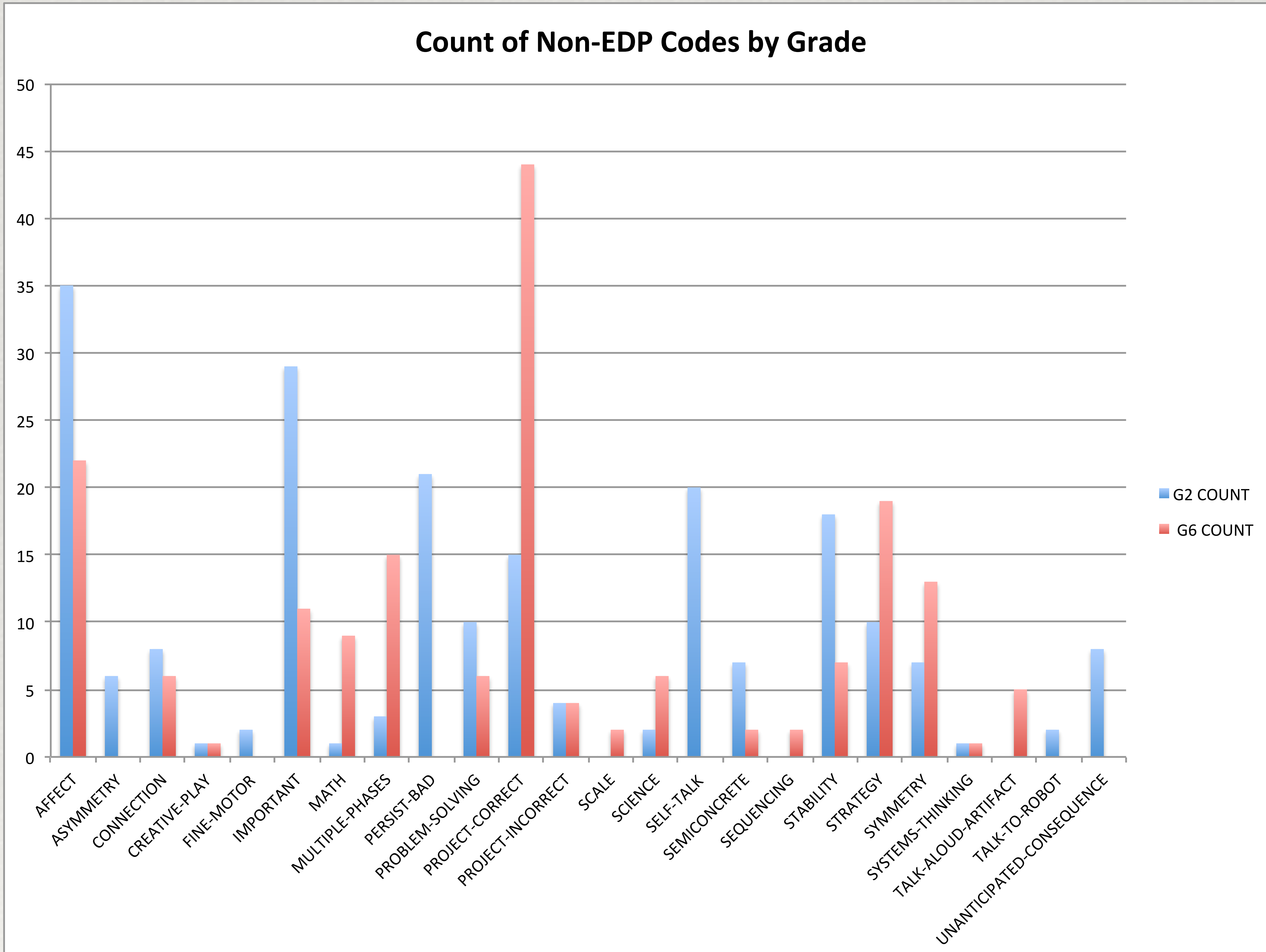

EDP Phase Timeline - Grade 2
Plan
Research
Build
Program
Evaluate
0:00:00
0:07:12
0:14:24
0:21:36
0:28:48
0:36:00
0:43:12
0:50:24
0:57:36
1:04:48
1:12:00



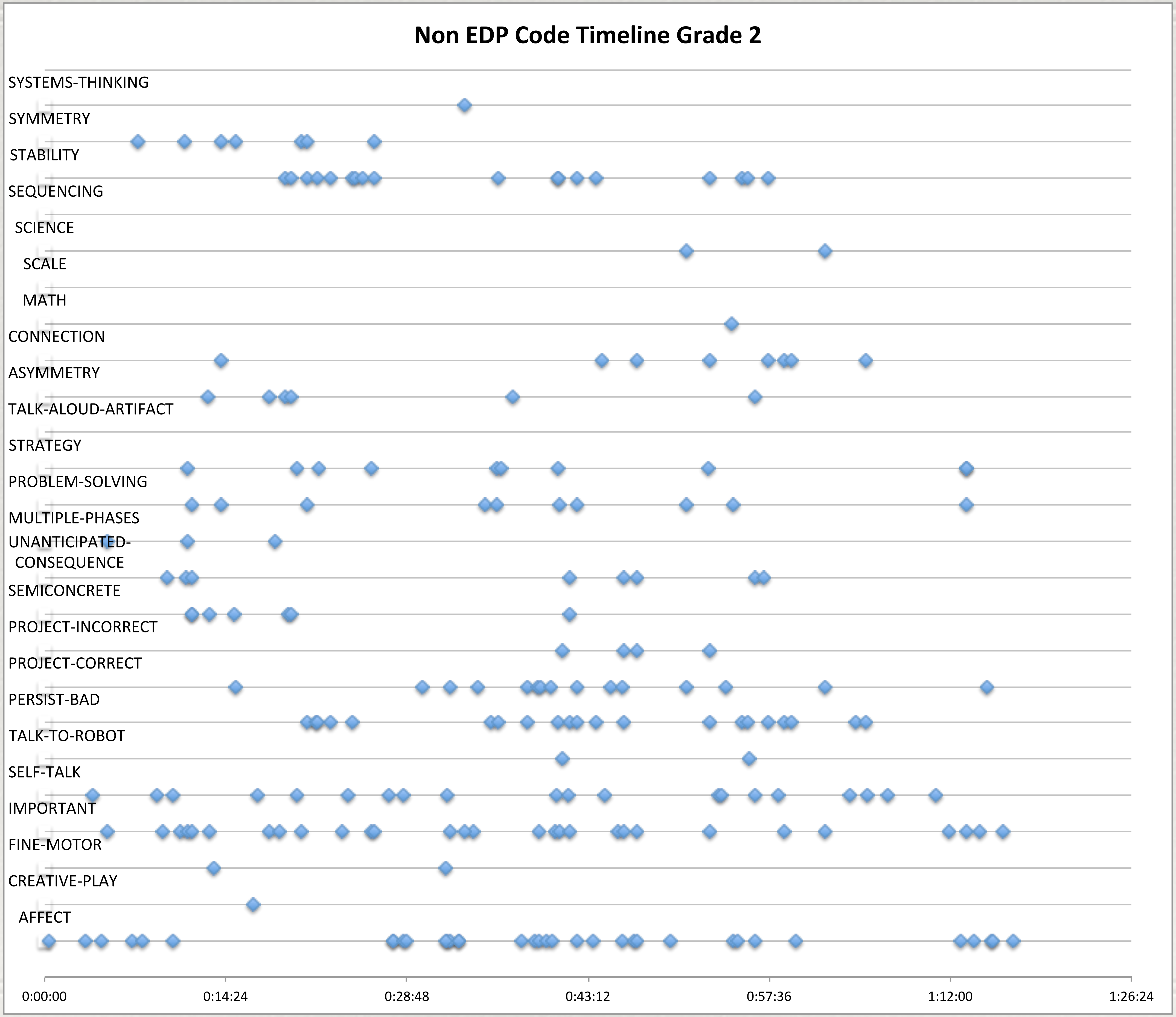
Count of EDP Subcode Phase by Grade
40
35
30
25
20
15
10
5
0
PLAN
RESEARCH
BUILD-NORMAL
BUILD-REBUILD
PROGRAM-NORMAL
PROGRAM-REPROGRAM
EVALUATE-PHYSICAL
EVALUATE-VERBAL
EVALUATE-VISUAL
EVALUATE-SYSTEM
G2 Count
G6 Count

Time in EDP Subcode Phase by Grade

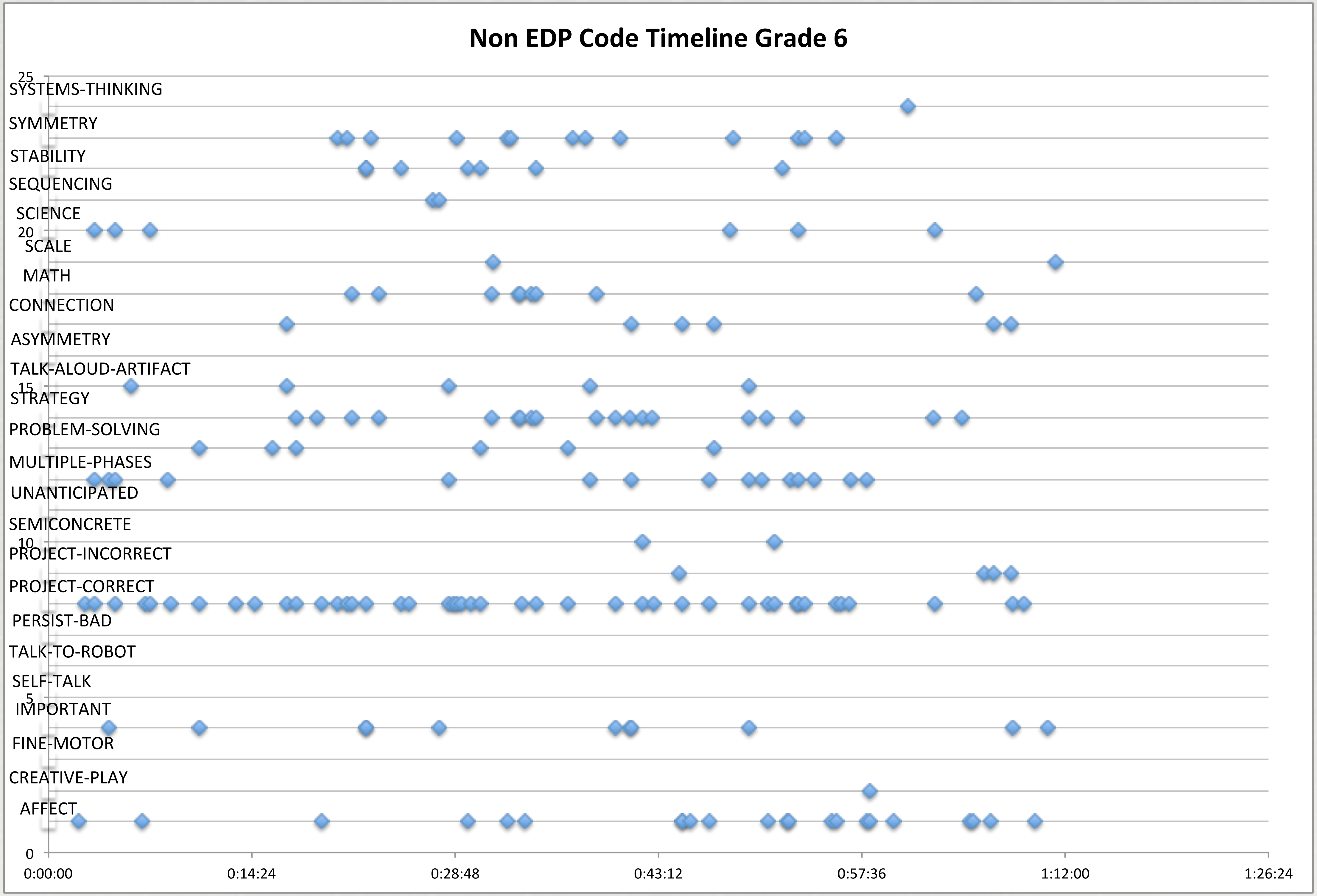




Count of Non-EDP Codes by Grade
50
45
40
35
30
25
20
15
10
5
0
AFFECT
ASYMMETRY
CONNECTION
CREATIVE-PLAY
FINE-MOTOR
IMPORTANT
MATH
MULTIPLE-PHASES
PERSIST-BAD
PROBLEM-SOLVING
PROJECT-CORRECT
PROJECT-INCORRECT
SCALE
SCIENCE
SELF-TALK
SEMICONCRETE
SEQUENCING
STABILITY
STRATEGY
SYMMETRY
SYSTEMS-THINKING
TALK-ALOUD-ARTIFACT
TALK-TO-ROBOT
UNANTICIPATED-CONSEQUENCE
G2 COUNT
G6 COUNT



Non EDP Code Timeline Grade 2
SYSTEMS-THINKING
SYMMETRY
STABILITY
SEQUENCING
SCIENCE
SCALE
MATH
CONNECTION
ASYMMETRY
TALK-ALOUD-ARTIFACT
STRATEGY
PROBLEM-SOLVING
MULTIPLE-PHASES
UNANTICIPATED-CONSEQUENCE
SEMICONCRETE
PROJECT-INCORRECT
PROJECT-CORRECT
PERSIST-BAD
TALK-TO-ROBOT
SELF-TALK
IMPORTANT
FINE-MOTOR
CREATIVE-PLAY
AFFECT
0:00:00
0:14:24
0:28:48
0:43:12
0:57:36
1:12:00
1:26:24



Non EDP Code Timeline Grade 6
SYSTEMS-THINKING
SYMMETRY
STABILITY
SEQUENCING
SCIENCE
SCALE
MATH
CONNECTION
ASYMMETRY
TALK-ALOUD-ARTIFACT
STRATEGY
PROBLEM-SOLVING
MULTIPLE-PHASES
UNANTICIPATED
SEMICONCRETE
PROJECT-INCORRECT
PROJECT-CORRECT
PERSIST-BAD
TALK-TO-ROBOT
SELF-TALK
IMPORTANT
FINE-MOTOR
CREATIVE-PLAY
AFFECT
25
20
15
10
5
0
0:00:00
0:14:24
0:28:48
0:43:12
0:57:36
1:12:00
1:26:24

Causal Reasoning

- *Grade 2 student could not project out consequences of his design decisions*
- *Grade 2 student could troubleshoot and attempt to fix problems after testing and teacher questioning (concrete and semi-concrete evaluation)*
- *Grade 2 student transitioning to concrete operation stage, lacks causal reasoning, formal operations would allow mental projection of design choices beforehand*
- *Previous informal research showed fine motor at grade K and building at grade 1 to be primary challenges*

Projection Data

Code	Gra	Grade 6
Persist in non-optimal design	21	0
Correct Projection	15	44
Unanticipated consequences	8	0

Grade 2 Clip

Transcript

Any ideas why it did not work? *No*

Which block makes the car go? *[Points to last one.]*

I think I am forgetting something. [Traces wires and realizes problem.]

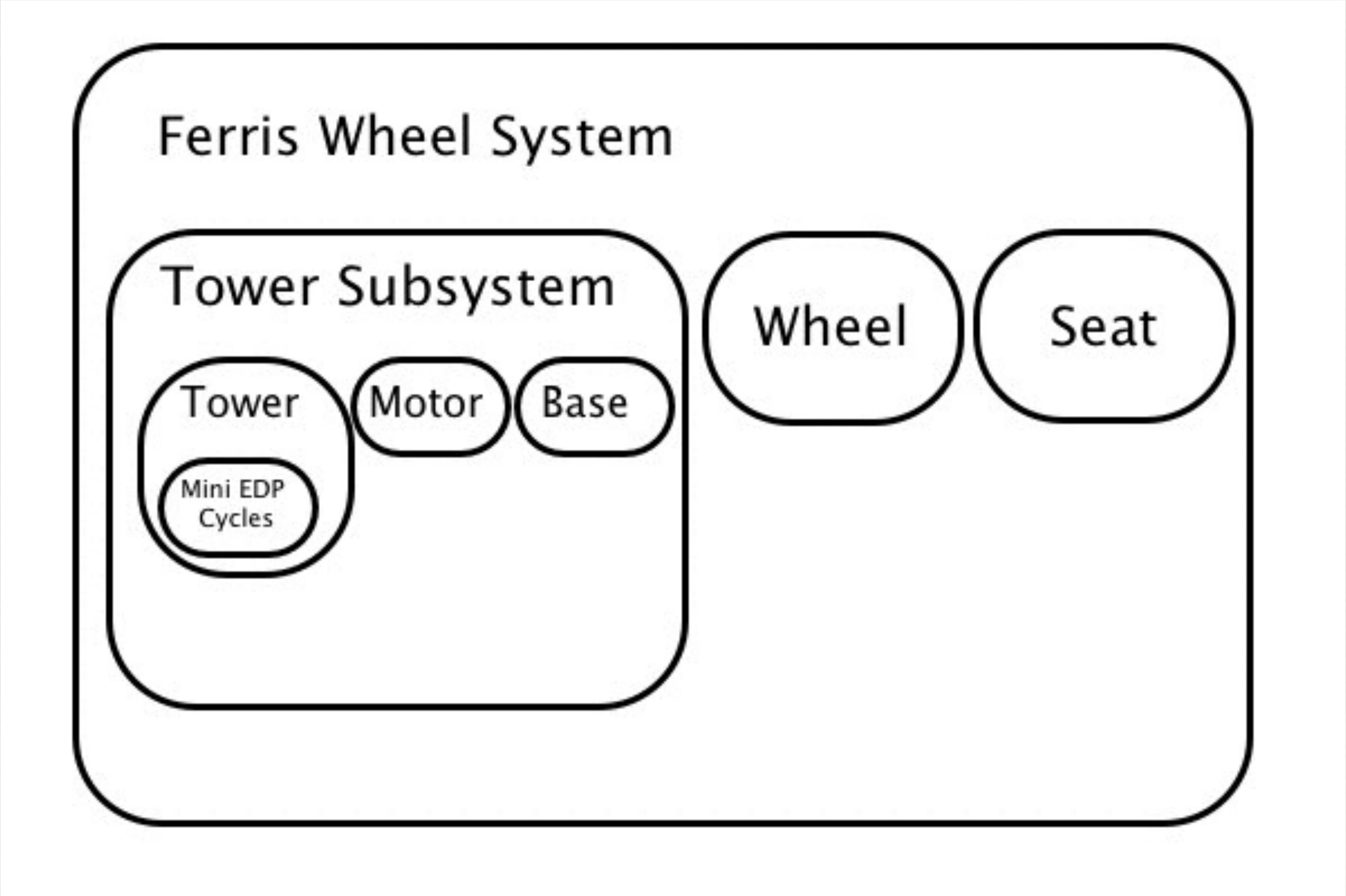
It's supposed to go up here. [Fixes motor not connected issue.]

Grade 6 Clip

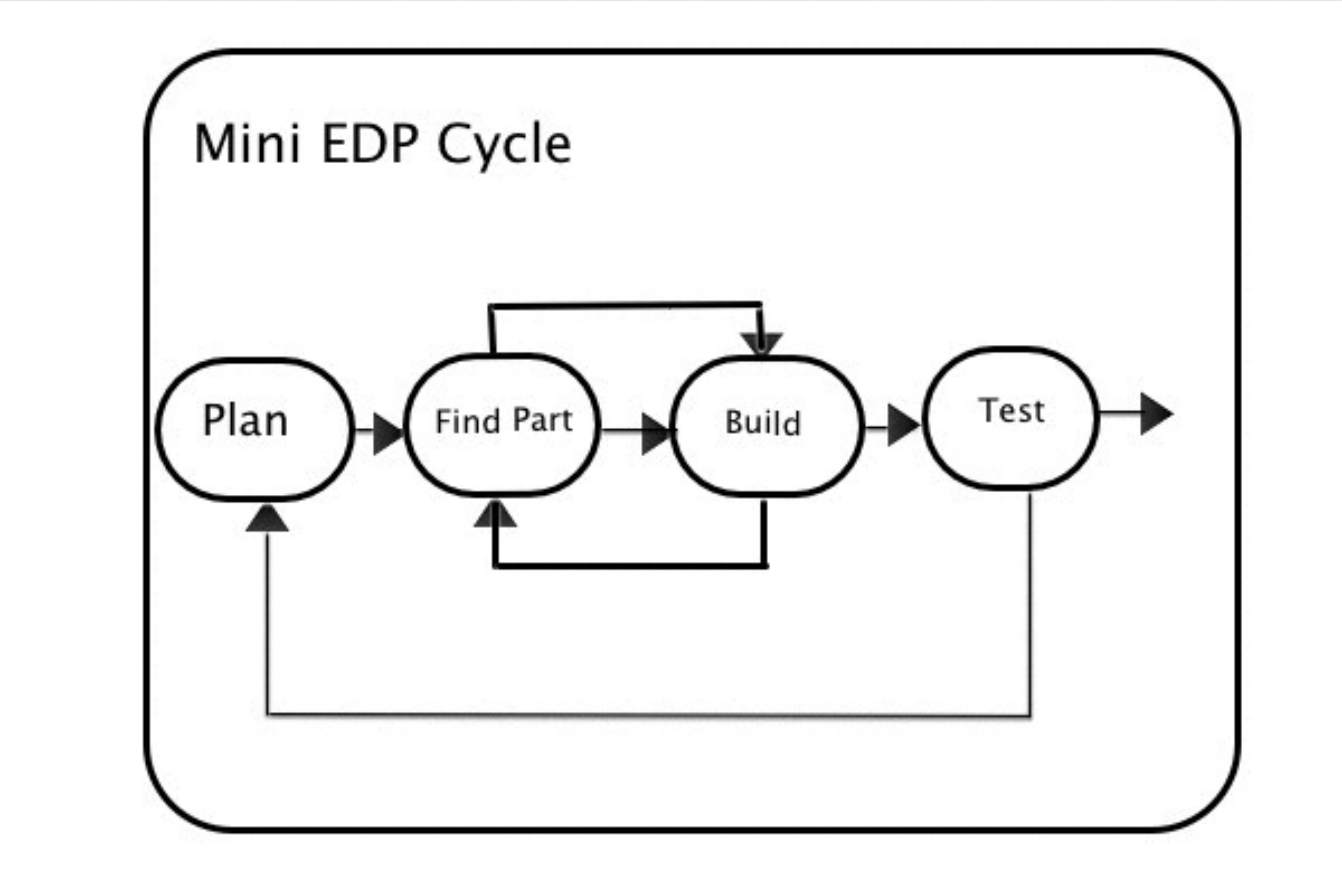
Transcript

- *[00:20:29] [PLAN] BOY 11: I was thinking that I could have one that kind of connects on both sides but then all this would get in the way. So then I couldn't really have it go around. [PROJECT-CORRECT] [SYMMETRY]*

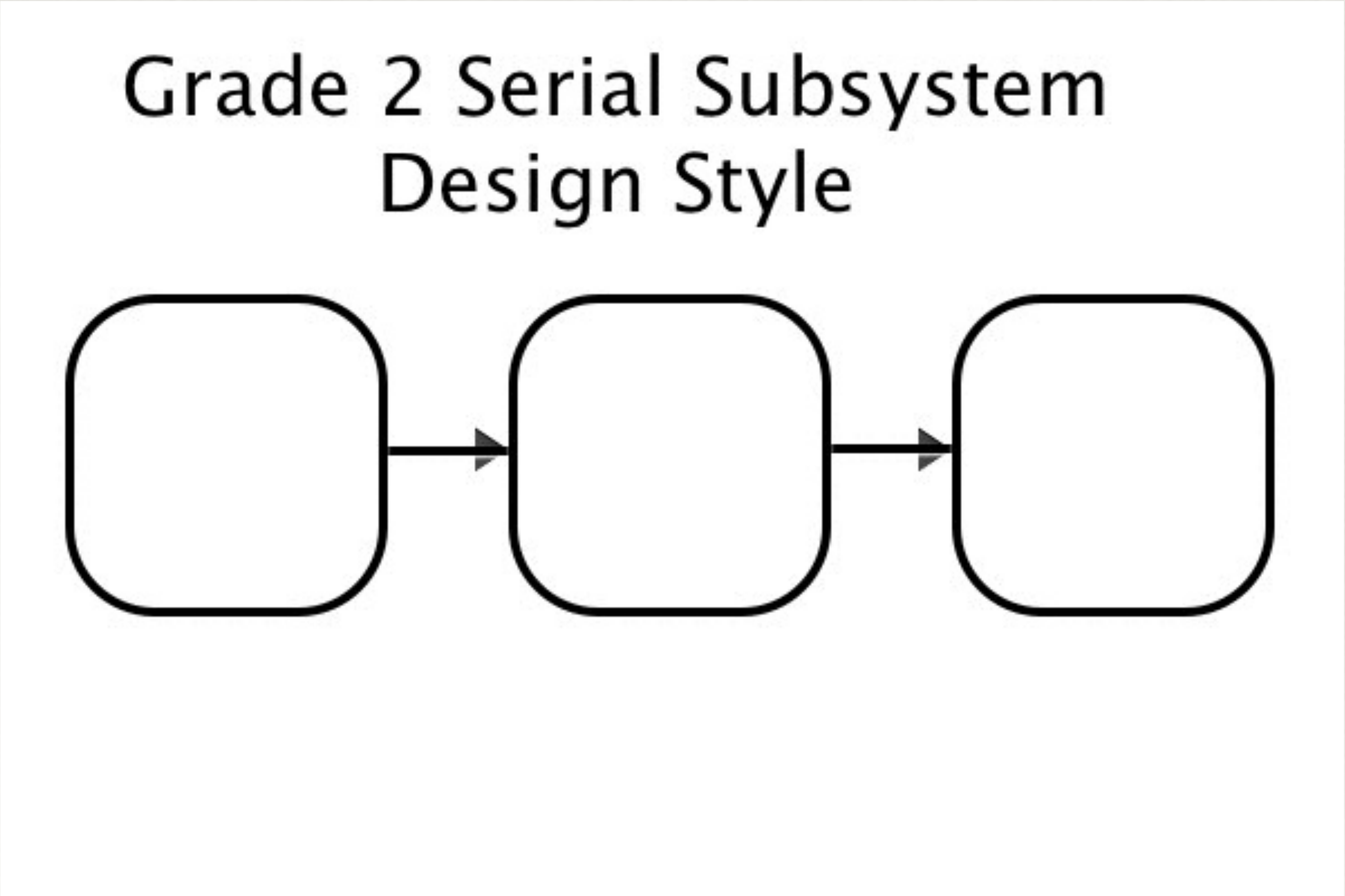
Grade 6 Cycles



Mini EDP Cycle

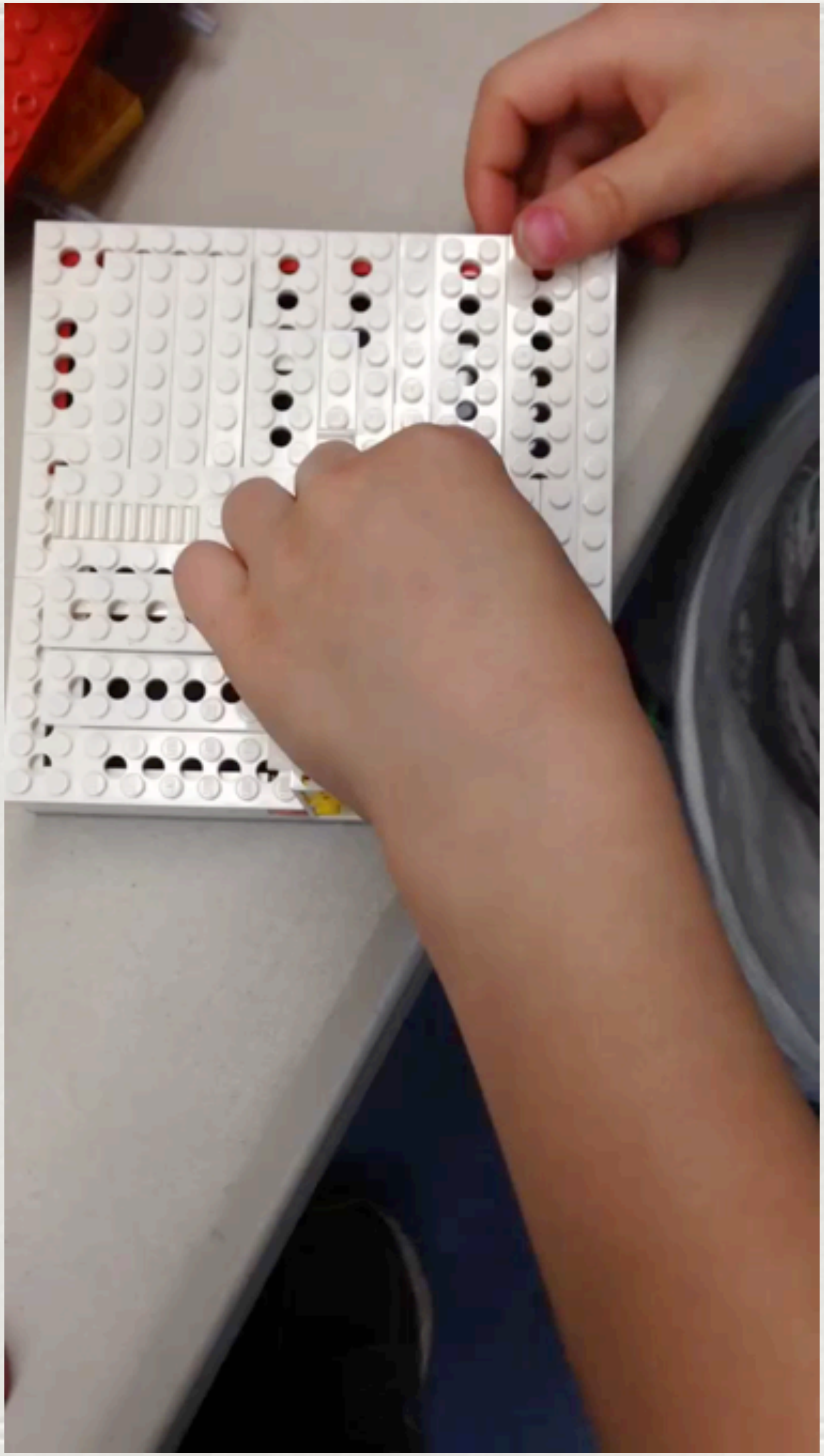


Grade 2 Process



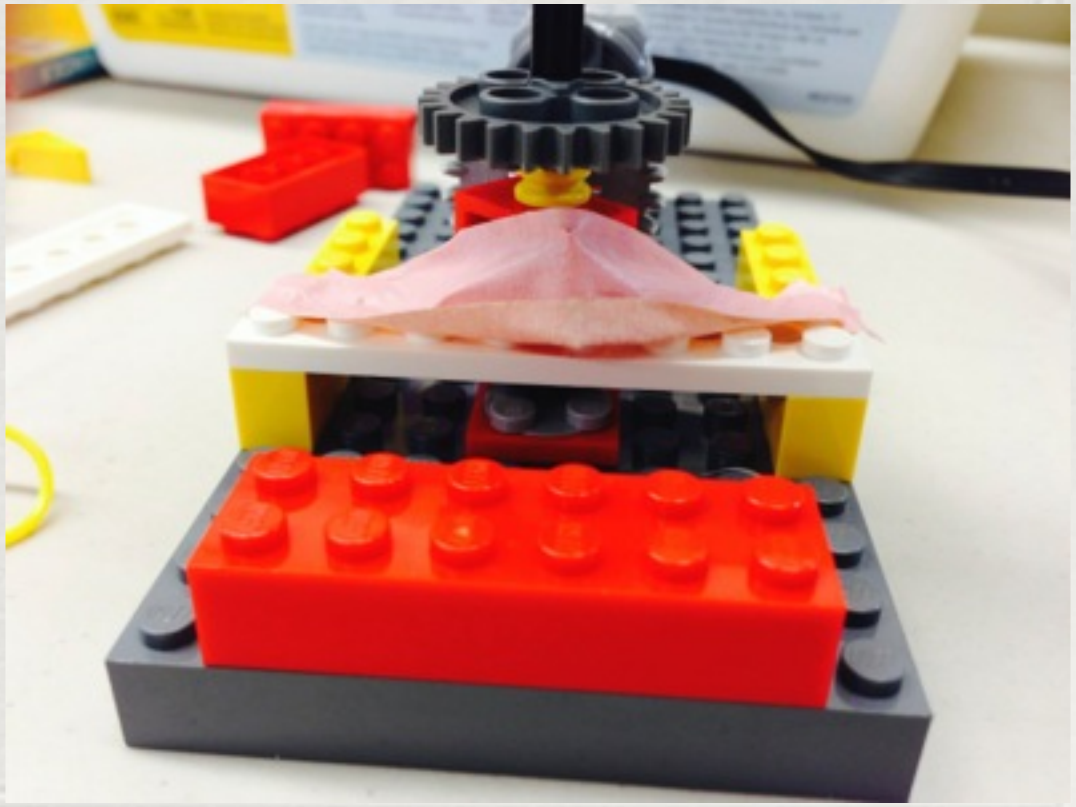
Grade 2 Persistence

- *Grade 2 students persist in non-optimal design choices even when they manifest as very difficult (n=21)*
- *Likely reasons: causal reasoning, single variable focus*
- *See video*



Design Concepts

- *Design concepts and aesthetics - Sixth grader was concerned and could verbalize issues around symmetry, scale,and stability*
- *Grade 1, 2 tape example*



Programming

- *Was not a major activity focus (8% G6, 3% G2)*
- *All mental projection*
- *4 of 10 second graders did not choose to use computer*

Affect

- *Grade 2 (n=35), Grade 6 (n=22)*
- *Mix of positive and negative*
- *Students show positive affect and satisfaction after finishing*
- *Do these go hand in hand?*

Other Strategies

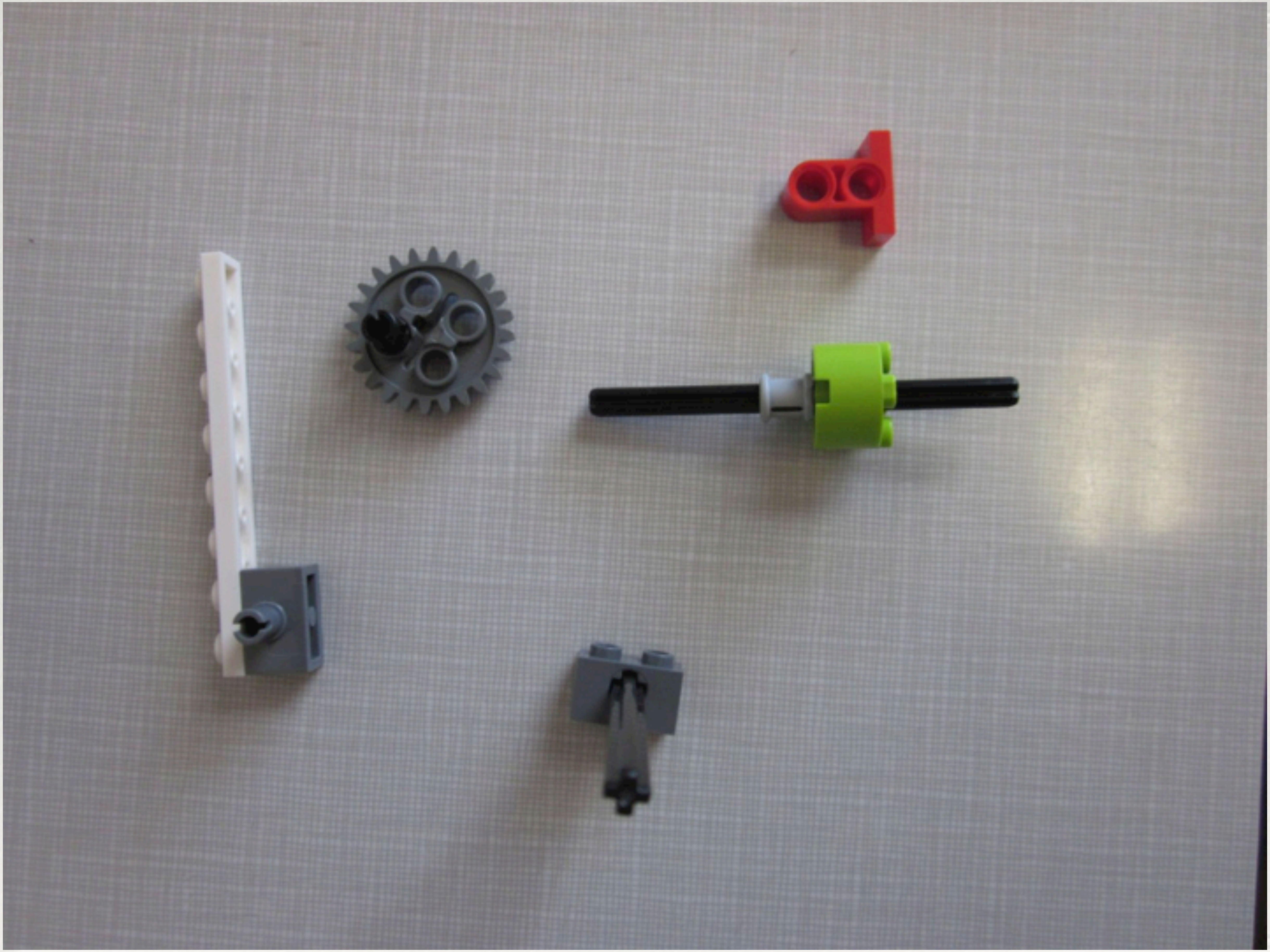
- *Changing viewing angle (G6, n=7; G2, n=4)*
- *Semi-concrete moves (G6, n=5; G2, n=7)*
- *Others: lifting car, using WeDo connection tab, checking connections, checking for power*

Educational Implications

- *Functional Analysis (Cross, 2008) - subsystems and top-down design*
- *Alternative ideas and starting over*
- *Teacher questioning to stimulate causal reasoning*
- *Stability, symmetry, balance, scale, and center of gravity*

LEGO Specific

- *Key connector pieces*
- *Cross to cross for axle connections*
- *Motor connections*
- *Motor drive trains*



LEGO WeDo Programming

- *WeDo Programming*
  - *Generally clear and easy to use*
  - *Confusion between Motor on For and Wait For*
  - *Multiple meanings of Motor This Way depending on context*
  - *Interlocks could be bigger*
  - *Macintosh specific issues*

Research Protocol

- *Multiple EDP phases*
- *Verbal and physical "tracks" can be different*
- *Talk aloud artifacts*
- *Discernability*

Study Limitations

- *Small sample size (n=2)*
- *Difference in levels*
- *Lack of gender diversity*
- *Lack of age diversity*
- *Methodology constraints*

Future Research

- *More students, girls, levels*
- *Hone in on causality*
- *Define learning progression*

Resources

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