Cross Case Analysis of Elementary Engineering Task

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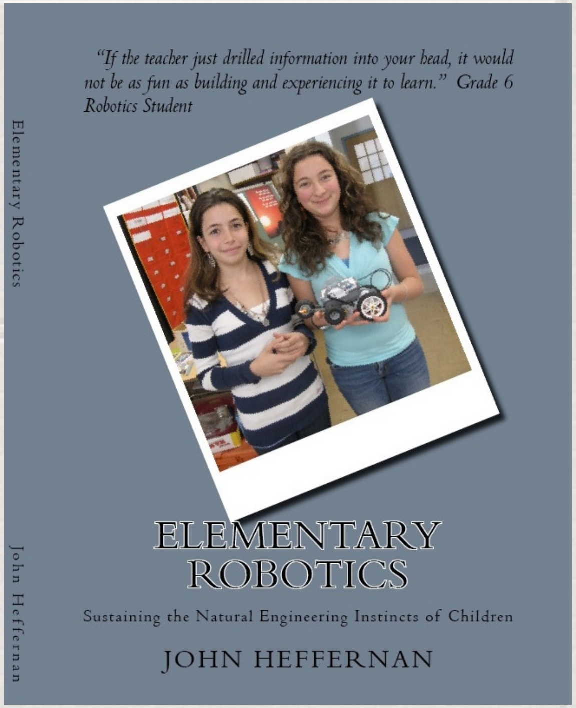
Problem Statement

- *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*

Project Background

- *Robotics seemed very promising*
- *Developed PK-6 curriculum book*
- *What was known already especially at elementary as students develop rapidly?*
- *How could I contribute?*
- *Preliminary research and literature review*



Robotic and STEM

Engineering design experiences including robotics, given sufficient time, appropriate pedagogy, and teacher scaffolding, results in STEM content and process skills increases and STEM interest and self-efficacy gains.

Problem Solving

- *changes with age and experience (Roden, 1997, 1999),*
- *can be affected by the tools and materials used (Norton, McRobbie, & Ginns , 2007),*
- *is affected by student perceptions of scientists (and presumably engineers) (Sullivan & Lin, 2012),*
- *can reveal embedded hierarchies of problems such as macro, meso, and micro levels (McRobbie, Stein, & Ginns, 2001),*
- *many heuristic strategies for problem solving are already known by students (Barak & Zadok, 2009).*

EDP Research

- *Actual design processes differ from idealized, linear models (Crismond, 2001; Johnsey, 1993; McRobbie et al., 2001; Welch, 1999)*
- *More experienced designers spend more time up front on problem scoping and continue to do so throughout the process (Cardella, Atman, Turns, & Adams, 2008)*
- *The number of alternative solutions considered generally correlates with solution quality (Atman et al. , 2007)*
- *Time spent correlates positively with design quality (Atman et al., 2007)*
- *Experts use more content knowledge (Crismond, 2001)*
- *Experts use general principles and use the EDP more effectively (Crismond, 2001)*
- *Teachers need to provide instruction and scaffolding for students in the application of science and general problem solving and design processes.*
- *Significant changes can be seen in engineering processes over time.*

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

Planning and Drawing

- *Results are mixed as to the utility of drawing and the capability of younger students to plan. Some positive results were found in tightly constrained problems with familiar materials (M. D. Portsmore, 2011). However, other studies find that young students largely skip the planning phase and the reason for this are developmental constraints (Anning, 1994; Fleer, 1999). It is possible that children can accomplish tasks ahead of projected developmental milestones in constrained tasks with familiar materials but this may not be the case in the more general case of open-ended engineering challenges where knowledge transfer must occur.*
- *Planning strategies may depend on variety of factors such as the problem itself, student age, gender, and whether or not the student has an initial solution to the problem (Gustafson & Rowell, 1998) .*

Designerly Play

The interactive and autonomous characteristics of robots make them especially efficacious for engaging the designerly play instincts of children and that this play changes from fantasy play to a more subdued form of play as children progress through elementary school (Outterside, 1993; Fleer, 1999; Mioduser, Levy, & Talis , 2007; Levy & Mioduser, 2008; Sullivan, 2011)

Causal Reasoning

- *elementary robotics curriculum and instruction should teach both data based and mechanism based approaches to troubleshooting (Kuhn & Dean, 2004)*
- *curriculum is needed to help students apply control of variables and other scientific reasoning skills (Kuhn, 2007)*
- *the development of scientific reasoning - of which causal reasoning is an important component - is gradual, continuous, and not a discrete developmental milestone like Piagetian conservation (Kuhn, Schauble, & Garcia-Mlia, 1992)*
- *self-directed practice alone (such as open-ended engineering challenges) is sufficient to cause gains in scientific and causal reasoning (Kuhn, Schauble, & Garcia-Mlia , 1992)*
- *engineers use both prediction and inference in their design processes and elementary engineering challenges create affordances to teach these skills.*

Connecting Math and Science

- *Expert designers apply science more than novice designers Crismond (2001),*
- *Design based science creates affordances for the application and understanding of science concepts and practices with teacher scaffolding (Fortus et al., 2005; Leonard & Derry, 2011; Mitnik et al., 2009; Puntambekar & Kolodner, 2005).*
- *It is not known how the application of mathematics and science works at the elementary level and how that changes with development.*

Gender

- *important factors for the lower self-efficacy of females and the achievement differences that have been shown are due to stereotype threat (Sullivan & Bers, 2013) , teacher differences in their treatment of boys and girls (Voyles, Fossum, & Haller, 2008), the lack of epistemological pluralism(Turkle & Papert, 1991) , and lack of previous experience,*
- *an examination of differences in engineering design processes of elementary age students as STEM gender-specific expectations solidify and how these differences relate to engineering self-efficacy may help inform the issue of STEM related gender differences.*

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?*

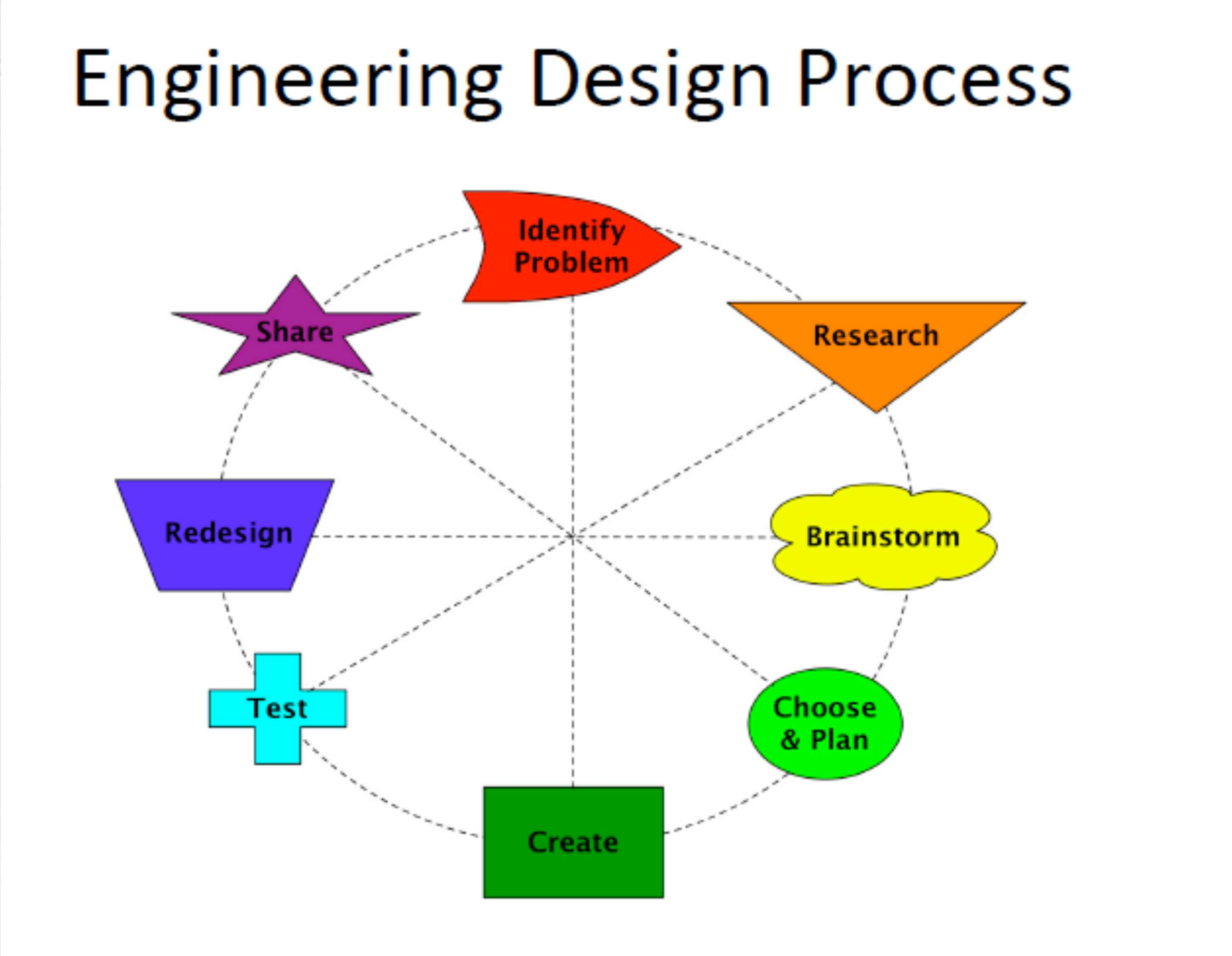
Frameworks

- *Constructivism (Piaget, 1969)*
    - *Map stages applicable to K-6 (preoperational, concrete operational, formal operational) to grade levels*
- *Designerly Play (Baynes, 1994)*
- *Constructionism (Papert, 1993), basis of curriculum*

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)*
- *Domain specific milestones for elementary engineering can be detected but may or may not be directly traceable to Piagetian milestones*

Portsmore (2011)



Bers et al (2014)

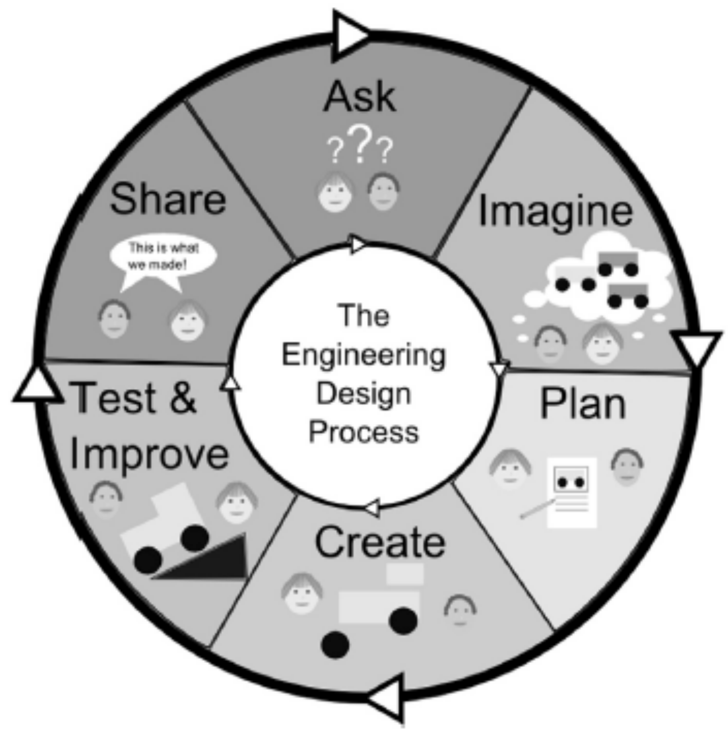
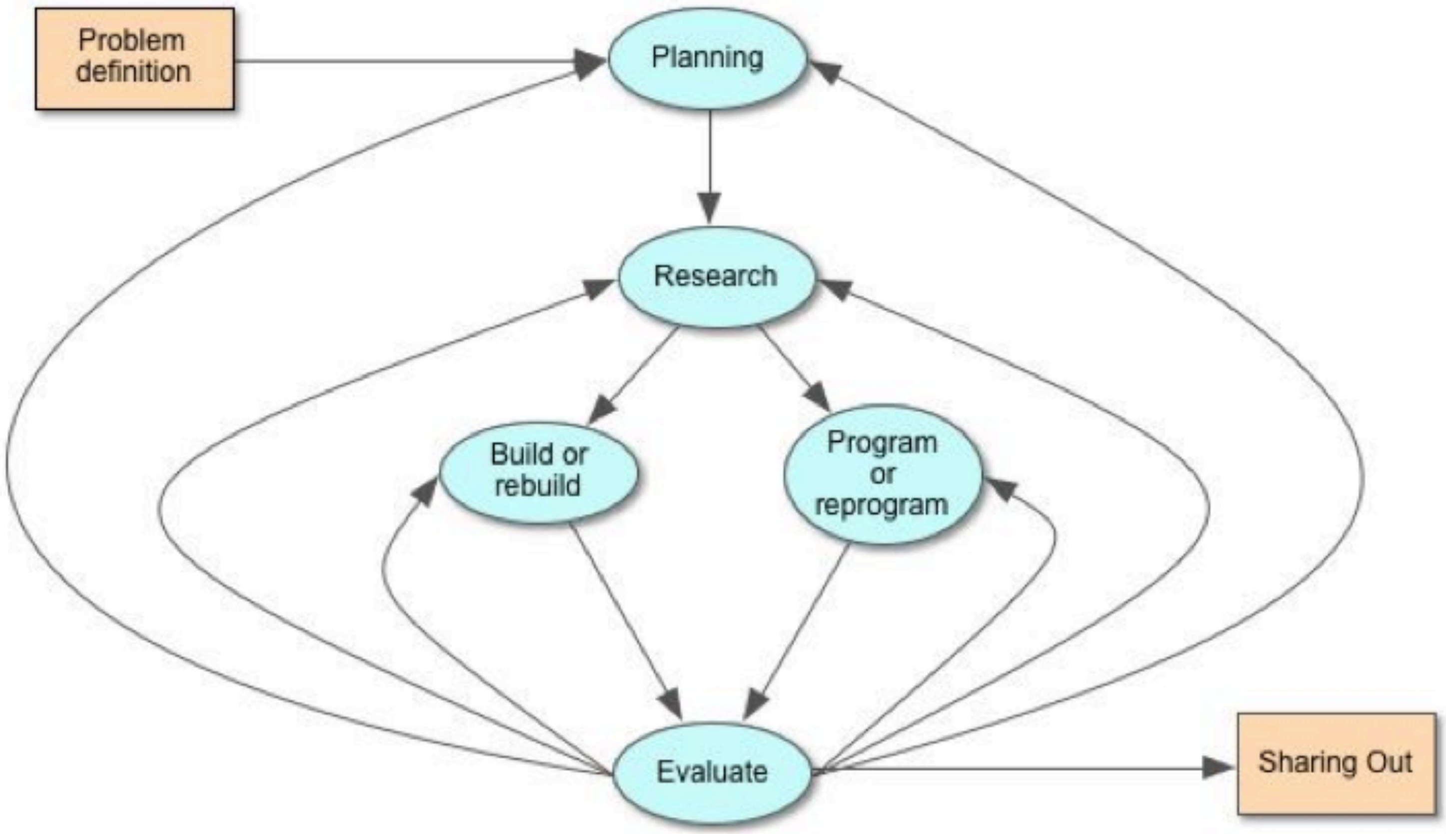
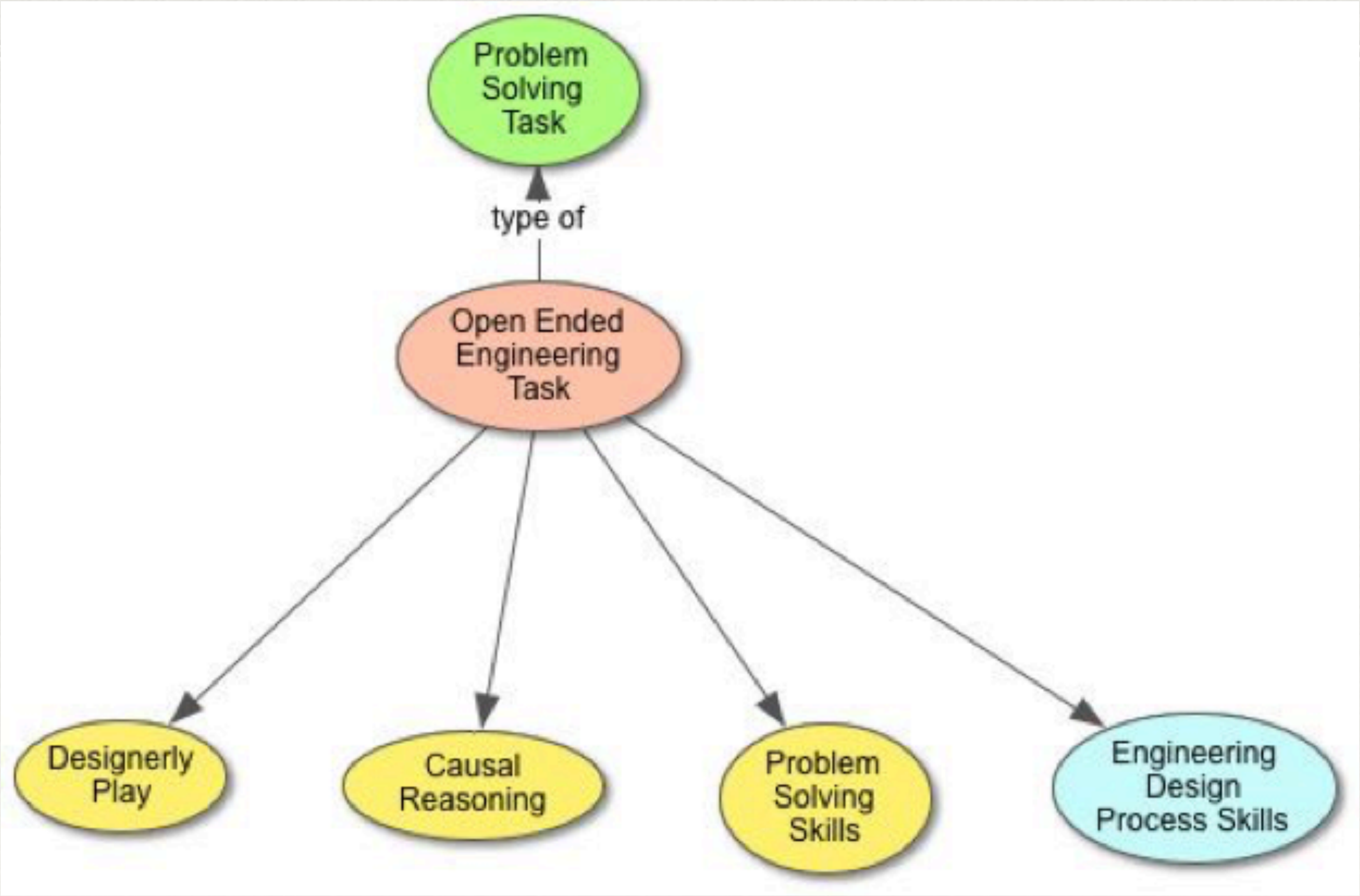


Fig. 4. An illustration of the engineering design process.



Engineering design process model for this study

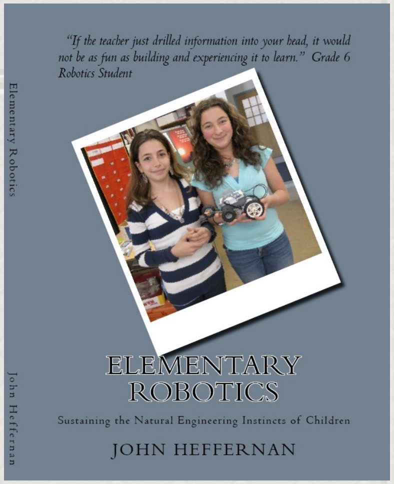
Conceptual Framework



Methodology

- *Qualitative, Cross Case, Cross-Sectional*
- *Semi-clinical video interview (Ginsburg, 1997)*
- *Talk aloud protocol (Ericsson & Simon, 1980)*
- *Film six second grade student and six grade six student doing same open-ended engineering task*
- *Transcribed and coded*
- *Qualitative and quantitive analysis of EDP and non-EDP codes and activity*

Curriculum, Instruction, Materials



- *Based on Elementary Engineering Curriculum*
- *Constructionist*
- *Combination of structured and open-ended activities*
- *Primarily engineering but math, science, and ELA also used*

Lego Robots directly tap into the creative play urge of children in a healthy and educational way. A PK-6 robotics curriculum (such as Elementary Engineering Curriculum) is needed to support and sustain the natural engineering instincts of young children until formal engineering education starts.

Setting and Participants

- *Rural PK-6 school*
- *6 typical boys and 6 typical girls*
- *Students started in K*

Data Collection

- *Video tape of sessions*
- *Associated build data for each prototype*
- *Programs*
- *Photos of prototype*

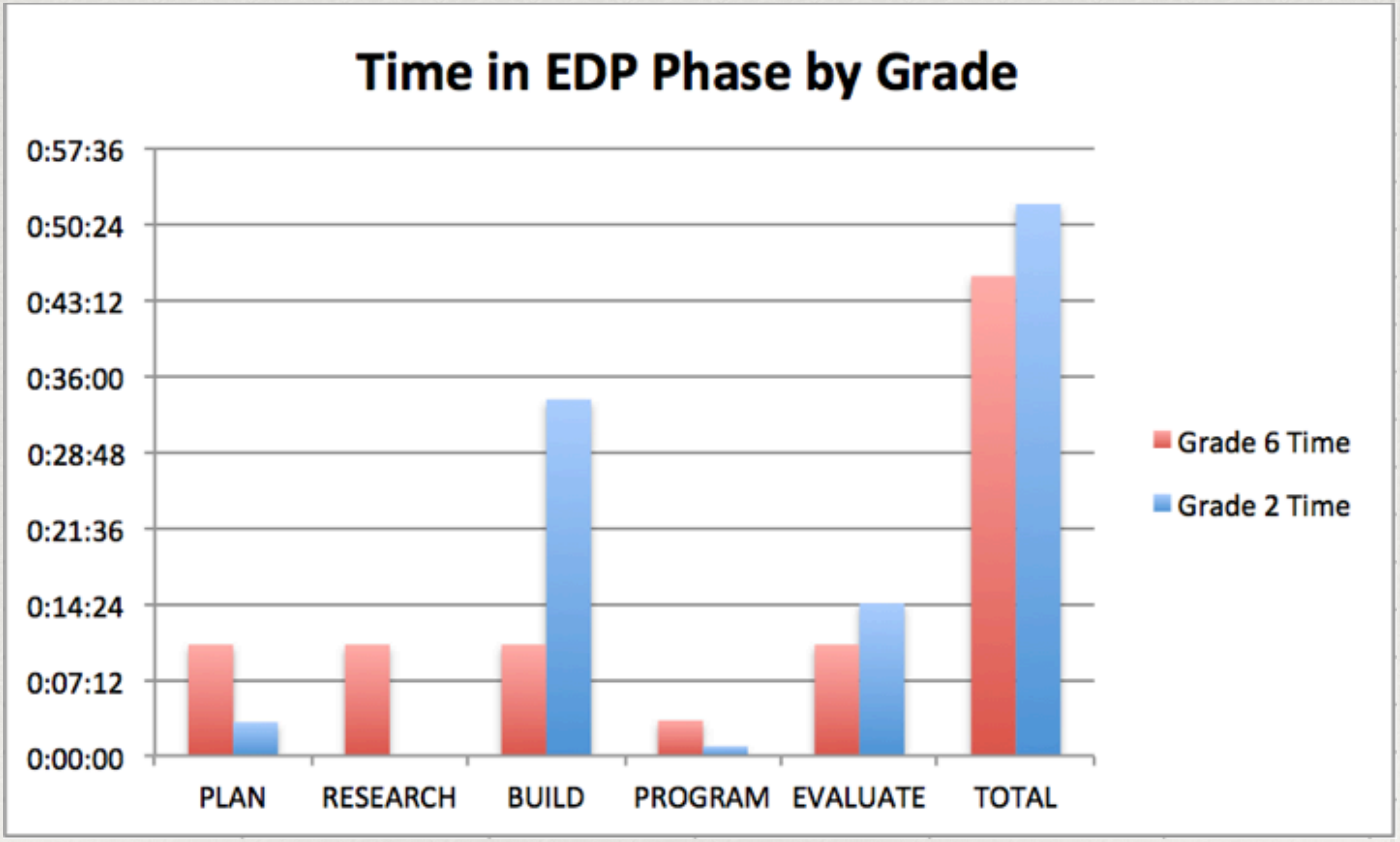
Data Analysis

- *Transcribe videotape sessions*
- *Add building and programming moves*
- *Spreadsheets and graphs of time coded EDP*
- *Spreadsheet and graphs of EDP related codes*
- *Other data (prototype data, post interviews)*

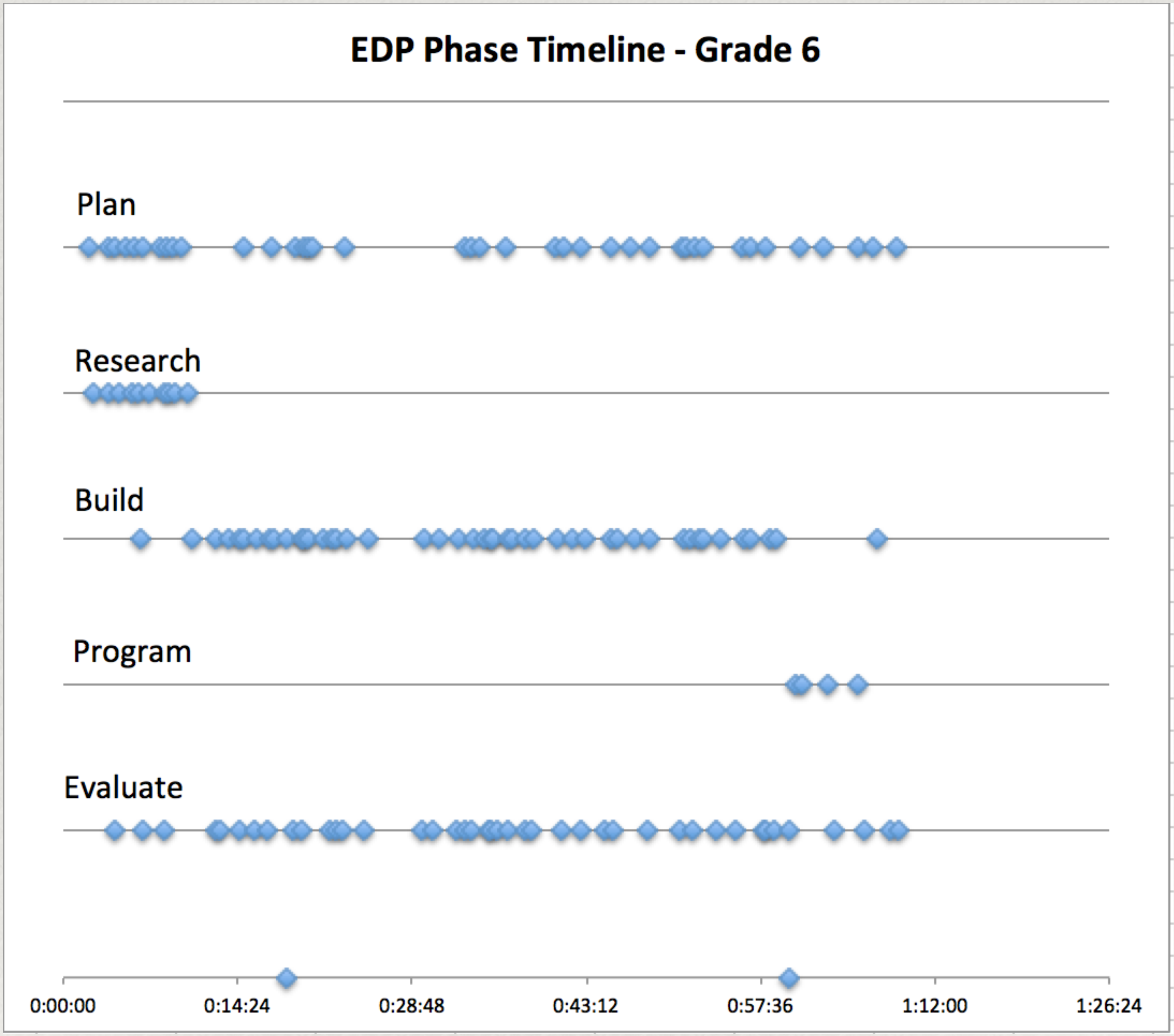
Grade 6 Clip

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]*



Time in EDP Phase by Grade
0:57:36
0:50:24
0:43:12
0:36:00
0:28:48
0:21:36
0:14:24
0:07:12
0:00:00
PLAN
RESEARCH
BUILD
PROGRAM
EVALUATE
TOTAL
Grade 6 Time
Grade 2 Time



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

Resources

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