Elementary Robotics Pilot Study

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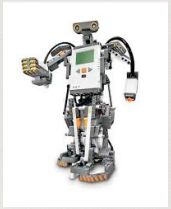
Tap creative play

- *Who is tapping into creative*

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.



Broad Research Questions

- *How do grade K to 6 students' robotics engineering skills and processes change over time in terms of construction and programming as related to the engineering design process?*
- *What impacts their ability to realize their design ideas at different ages? How are these related to developmental milestones?*
- *What are the educational implications of these findings for curriculum, instruction, and assessment?*
- *Can a model, framework, or learning progression be developed?*

Pilot Study Questions

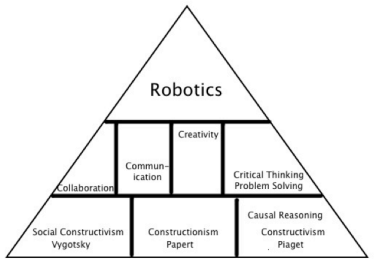
- *What are the best EDP models, theoretical frameworks, and methodologies to study the broad research questions? What does previous research have to say?*
- *For a grade 2 and grade 6 student, what are the differences and similarities in their design processes, barriers, and strengths? How might these be related to development?*

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),*

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*

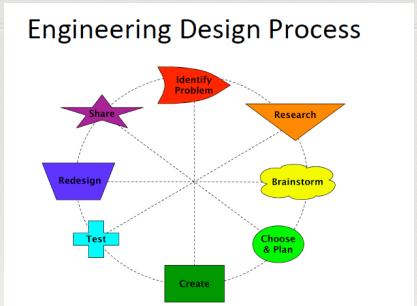


Relationship between theoretical frameworks, the 4 C's and Robotics

EDP Models

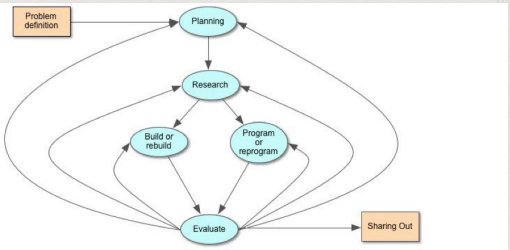
- *Engineering/design models (Portsmore, 2011; Crismond, 2012)*
- *Design process models are similar with different names and number of steps*
- *Design based science models include science processes*

Portsmore (2011)



Crismond & Adams (2012)

Design Strategies	Beginning vs. Informed Designer Patterns		Learning Goals where students…	Teaching Strategies where students…
	What Beginning Designers Do	What Informed Designers Do		
	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



Engineering design process model for this study

Welch (1999)

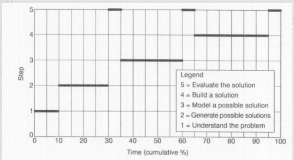


FIG. 3. Map of the five-step theoretical design process used in this study.

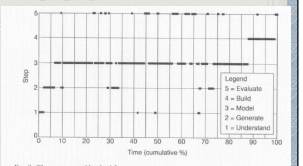


FIG. 2. The strategy used by dyad 5.

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	

Previous Research- Gap Analysis

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

Previous Research - Cognitive Summary

		Preoperational (K-2)					Concrete Operational (G2-G5)								Formal Operations (G6+)						Other		
Grade Level	**Composite Cognitive Skills**	*Egocentric*	*Primitive Reasoning*	*Unaware of how they get knowledge*	*Centration*	*Irreversibility*	*Solve problem logically with concrete objects*	*Inductive reasoning*	*Trial and error problem solving*	*Seriation*	*Concrete Operations (general)*	*Conservation*	*Transitivity*	*Reversibility*	*Classification*	*Decentering*	*Logical/systemic problem solving*	*Deductive reasoning*	*Abstract thought*	*Metacognition*	*Apply Math and Science*	*Design Concepts*	*Engineering Design Concepts*
2	Casual Reasoning																						
	Planning																						
	General																						
6	Causal Reasoning																						
	Planning																						
	General																						

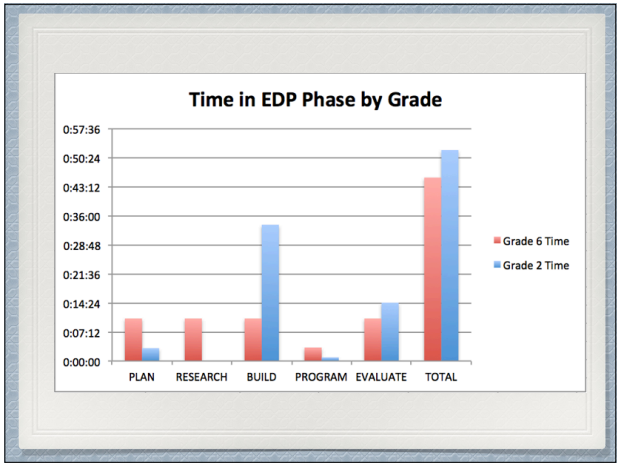
Table 2. Composite Skills, Stages, and Base Cognition.

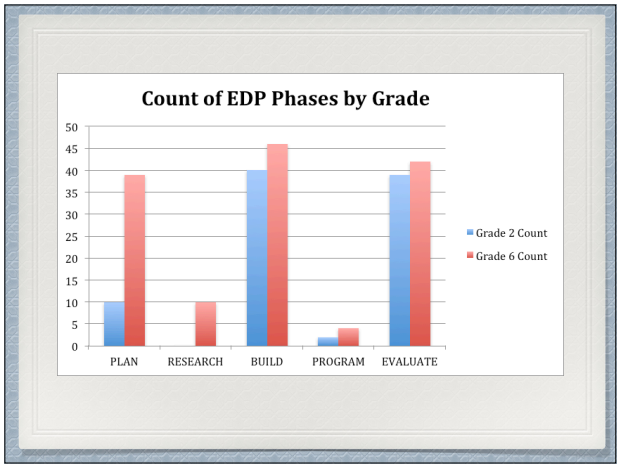
Pilot Study Goals

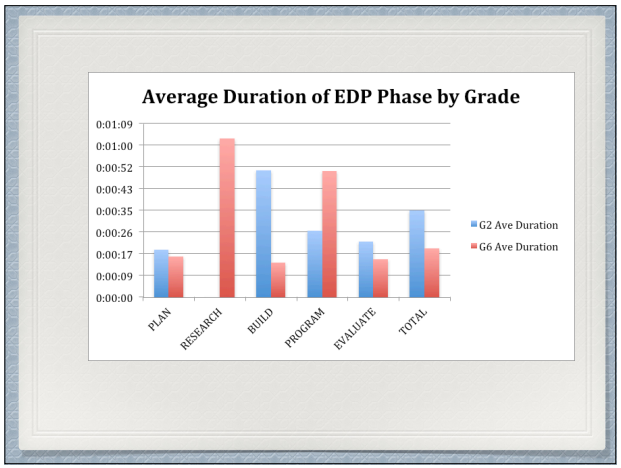
- *Establish task*
- *Establish methodology*
- *Establish data analysis*
- *Look for emergent themes*

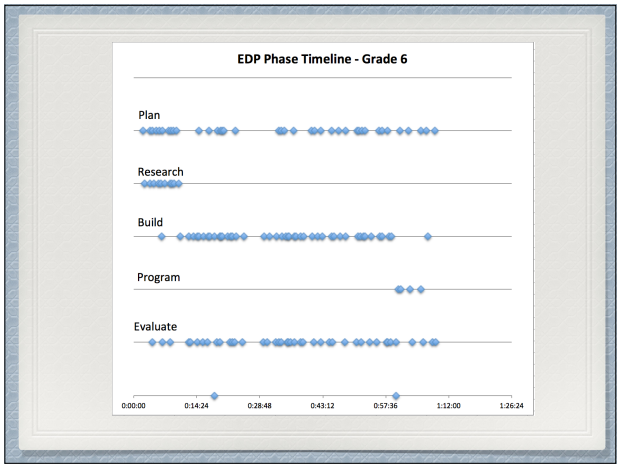
Methodology

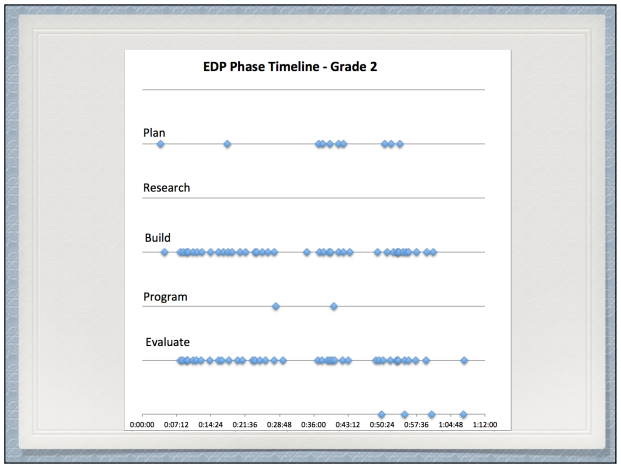
- *Qualitative, Cross Case, Longitudinal, Cross-Sectional (Yin, 2006) (Borman, Clarke, Cotner, & Lee, 2006)*
- *Semi-clinical video interview (Piaget & Inhelder, 1969)*
- *Microgenetic Analysis (Chinn, 2006; Siegler & Crowley, 1991)*
- *Film one second grade student and one grade six student doing same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

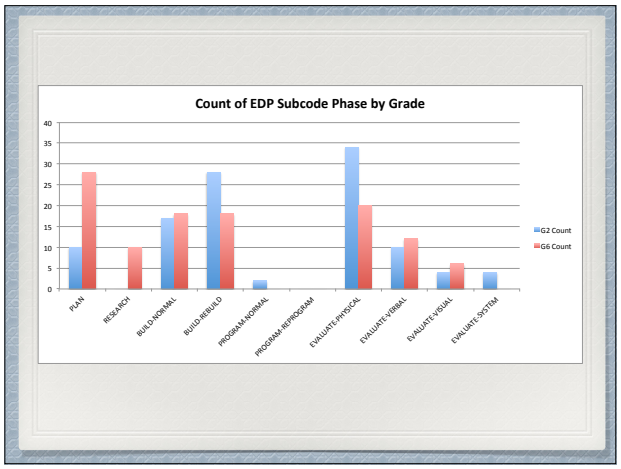

Time in EDP Phase by Grade
0:57:36
0:50:24
0:43:12
0:36:00
0:28:48
0:21:36
0:14:24
0:07:12
0:00:00
PLAN
RESEARCH
BUILD
PROGRAM
EVALUATE
TOTAL
Grade 6 Time
Grade 2 Time

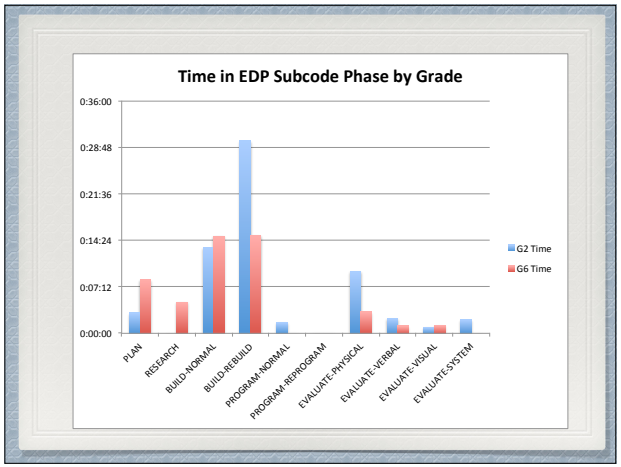

Count of EDP Phases by Grade
50
45
40
35
30
25
20
15
10
5
0
PLAN
RESEARCH
BUILD
PROGRAM
EVALUATE
Grade 2 Count
Grade 6 Count

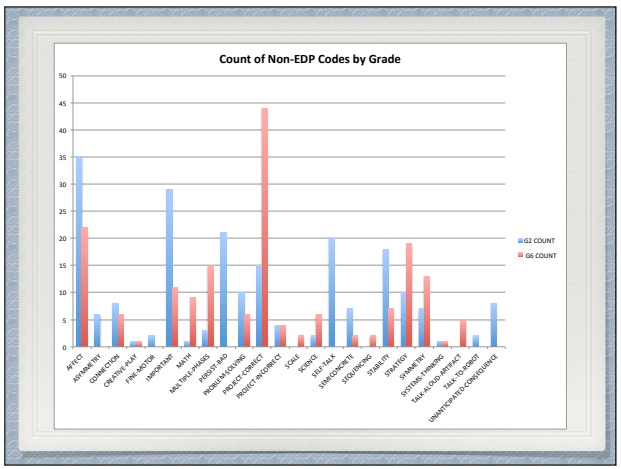

Average Duration of EDP Phase by Grade
0:01:09
0:01:00
0:00:52
0:00:43
0:00:35
0:00:26
0:00:17
0:00:09
0:00:00
PLAN
RESEARCH
BUILD
PROGRAM
EVALUATE
TOTAL
G2 Ave Duration
G6 Ave Duration


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





Projection Data

Code	Grade 2	Grade 6
Persist in non-optimal	21	0
Correct Projection	15	44
Unanticipated consequences	8	0

Causal Reasoning

- *Grade 2 student could not project out consequences of his design decisions (also centration, trial and error)*
- *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*

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.]

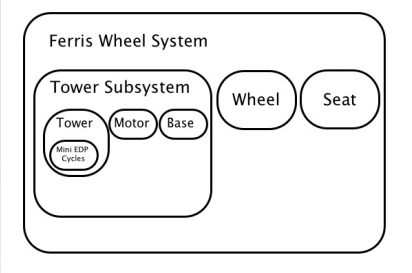
It's supposed to go up here. [Fixes motor not connected issue.]

Grade 6 Clip

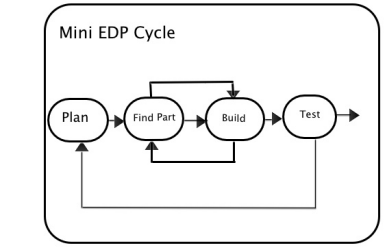
Transcript

- *[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]*

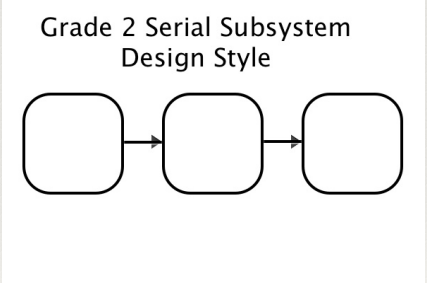
Grade 6 Cycles



Mini EDP Cycle

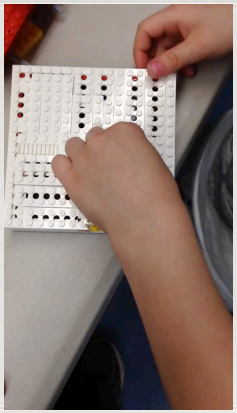


Grade 2 Process



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, reversibility, centration*
- *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*

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 building instruction*

Mapping to Cognitive Framework

Grade Level	Composite Cognitive Skills	Egocentric	Primitive Reasoning	Unaware of how they got knowledge	Centration	Irreversibility	Solve problem logically with concrete objects	Inductive reasoning	Trial and error problem solving	Seriation	Concrete Operations (general)	Conservation	Transitivity	Reversibility	Classification	Decentering	Logical/systemic problem solving	Deductive reasoning	Abstract thought	Metacognition	Apply Math and Science	Design Concepts	Engineering Design Concepts
2	Casual Reasoning	-			-	-	+	+	-		+												
	Planning (lack of)	-			-					-													
	Troubleshooting persistence (non-optimal)	-			-	-			-		+												
	General				-	-	+	+	+		+										+/-	+/-	+
6	Causal Reasoning							+	-		+					+	+	+	+		+		
	Planning									+								+	+				+
	Troubleshooting Persistence (optimal)										+			+		+	+		+	+			+
	General							+			+						+	+	+	+	+	+	+/-

Study Limitations

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

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*