THE MISSING E IN STEM

JOHN HEFFERNAN

Tech Teacher, Williamburg Schools

STEM PIPELINE

- STEM occupations are projected to grow by 17.0 percent from 2008 to 2018, compared to 9.8 percent growth for non-STEM occupations

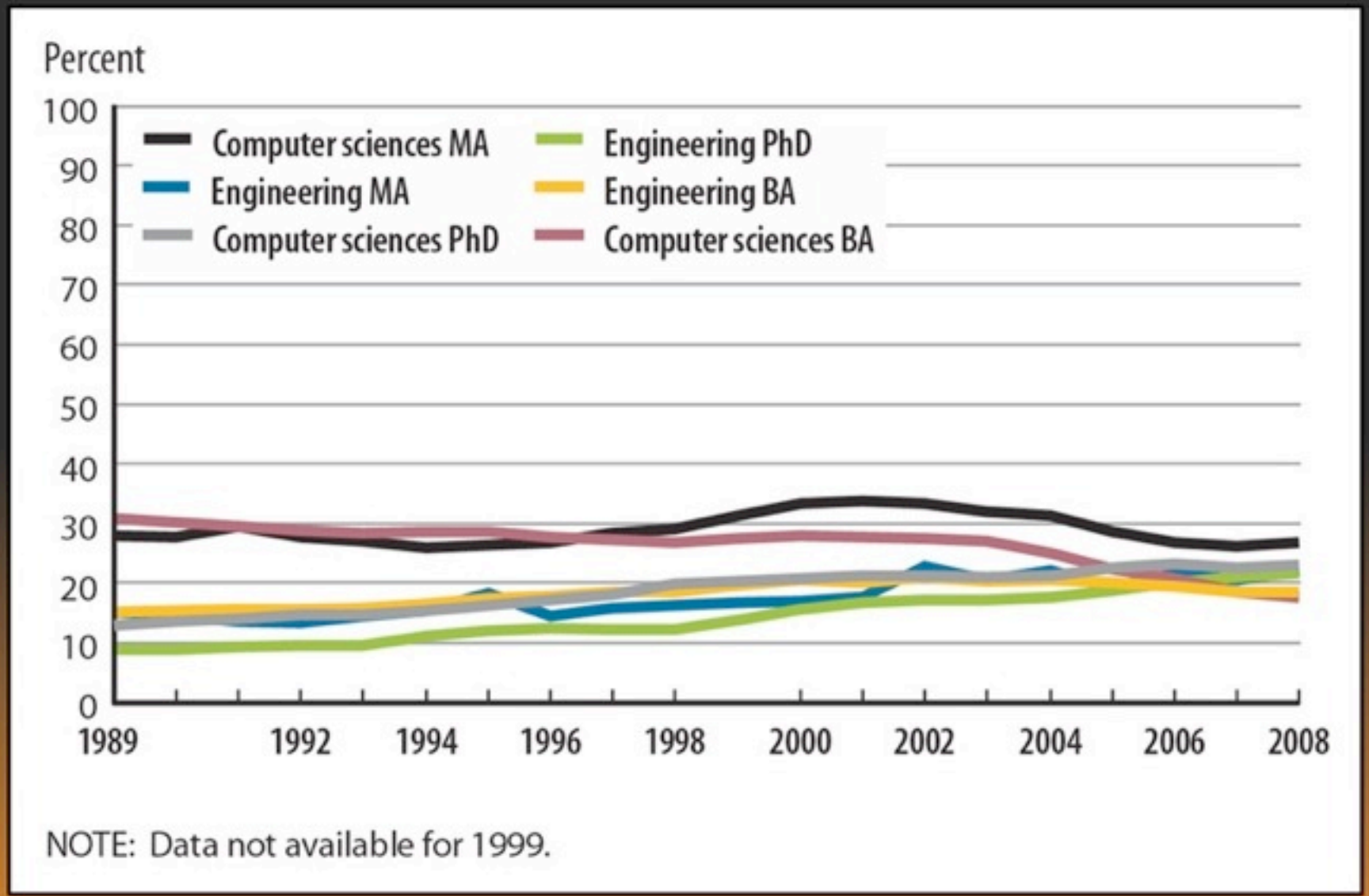
- STEM workers command higher wages, earning 26 percent more than their non-STEM counterparts

- We need creators of technology, not just consumers

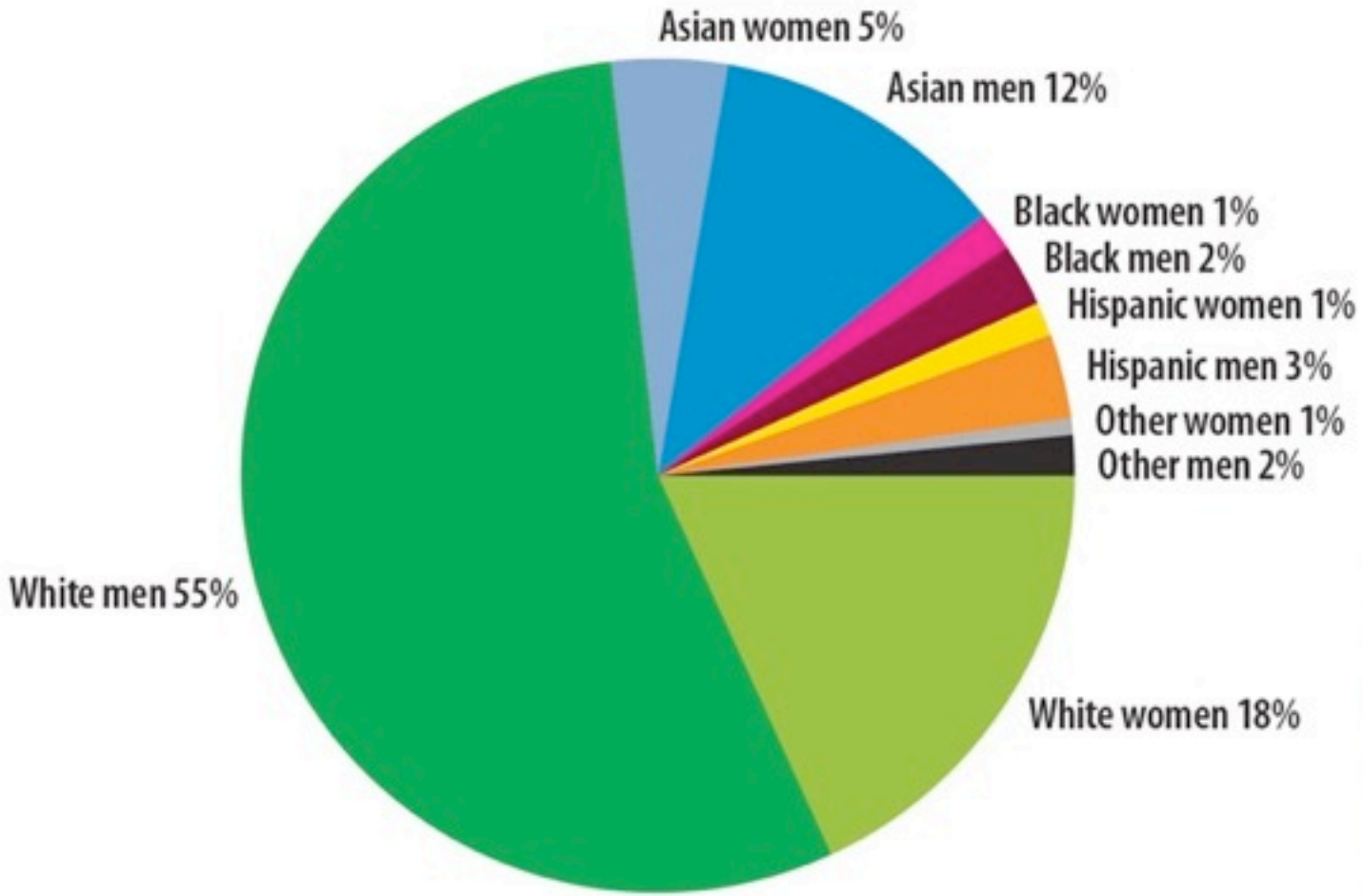
- Will we be STEM competitive in the new global economy?

US Dept of Commerce, 2011

Low participation fields for women: Computer sciences and engineering, 1989–2008

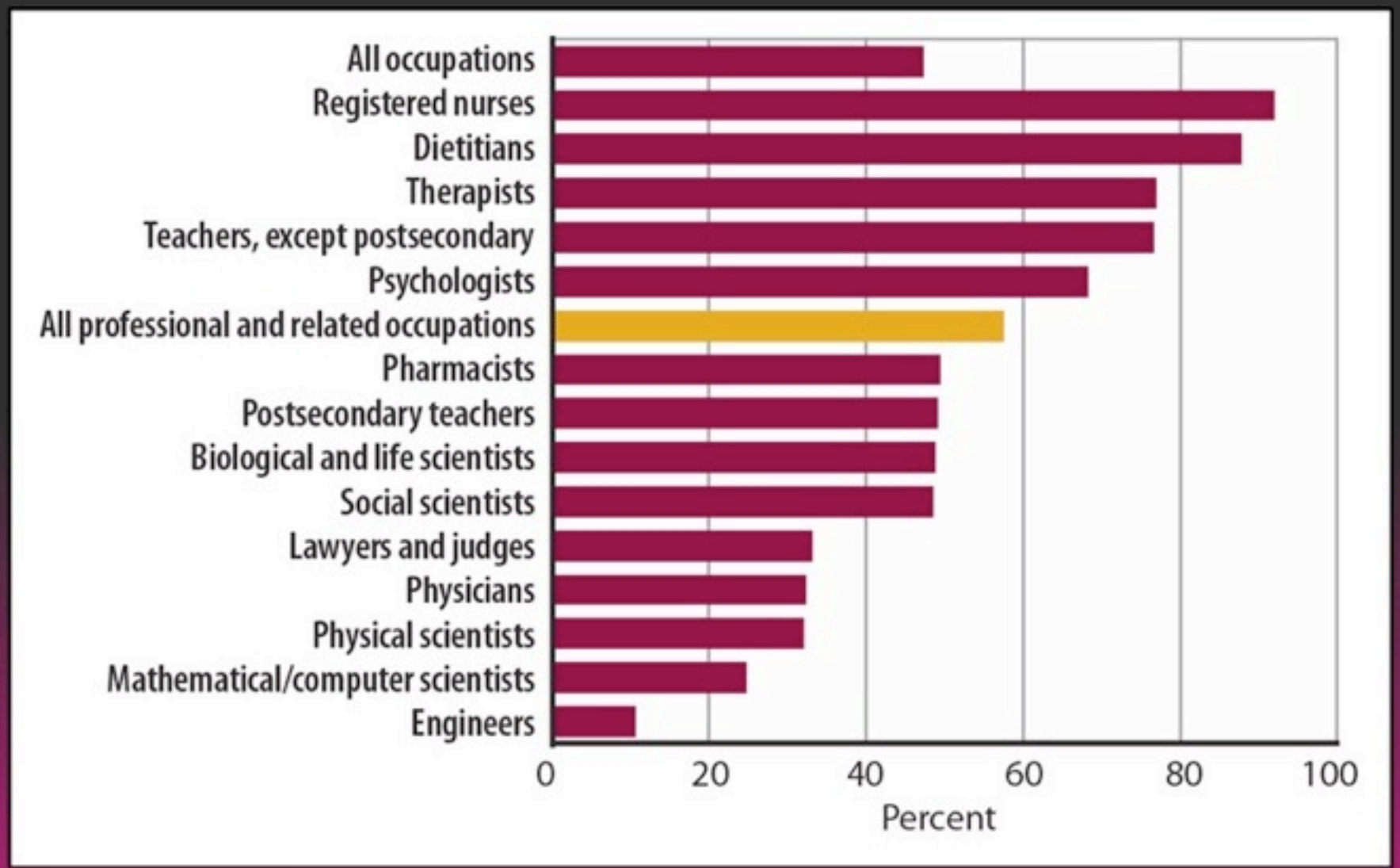


Scientists and engineers in science and engineering occupations: 2006



NOTE: Hispanic may be any race. Other includes American Indian/Alaska Native, Native Hawaiian/Other Pacific Islander, and multiple race.

Employed women 16 years and older as a percentage of selected occupations: 2009



NGSS FRAMEWORK

“Science, engineering, and technology permeate nearly every facet of modern life, and they also hold the key to meeting many of humanity’s most pressing current and future challenges. Yet too few U.S. workers have strong backgrounds in these fields, and many people lack even fundamental knowledge of them. This national trend has created a widespread call for a new approach to K-12 science education in the United States.”

NGSS - 2

Engineering and technology, defined in these broad ways, are included in the framework for several reasons. First, the committee thinks it is important for students to explore the practical use of science, given that a singular focus on the core ideas of the disciplines would tend to short change the importance of applications. Second, at least at the K-8 level, these topics typically do not appear elsewhere in the curriculum and thus are neglected if not included in science instruction. Finally, engineering and technology provide a context in which students can test their own developing scientific knowledge and apply it to practical problems; doing so enhances their understanding of science—and, for many, their interest in science—as they recognize the interplay among science, engineering, and technology. We are convinced that engagement in the practices of engineering design is as much a part of learning science as engagement in the practices of science [2].

NGSS - 3

- Engineering included under “Practices”
- MA will add actual tech/engineering standards

RESEARCH - BROPHY ET AL (2008)

- Good review of present state of PK-12 engineering education
- Significant research exists for STEM education as isolated subjects, engineering education and the integration of science, mathematics, technology, and engineering is not well understood
- P-12 engineering education must improve if the STEM shortage (and gender and ethnic imbalances) is to be addressed

RESEARCH - SCHUNN (2009)

- "Engineering involves using analytical and empirical processes to design complex systems that meet stated objectives and take into account specific scientific and societal constraints"

- Need for engineering education for both increasing the STEM pipeline (and increasing the diversity of engineers) and for general digital citizenship

- Specific K-12 engineering education needed for college level engineering, and not just math and science as been traditionally thought

- Engage children in solving significant design problems from the beginning

- Make visible models to support the design task

- Iterative design and redesign are better than sngle design cycles

- Provide sufficient time for exposure to engineering material

RESEARCH - SULLIVAN (2008)

- Pre and post testing done at summer robotics camp
- Looked at systems engineering gains
- Increase in engineering systems knowledge
- "...these outcomes are a result of both the affordances of the robotics environment itself and a pedagogical approach that emphasizes open-ended, extended inquiry."

RESEARCH - HYNES (2007)

- Teachers showed a significant increase in both engineering content knowledge and confidence in teaching engineering.
- Student results were not generally significant for attitudes towards engineering. However, student scores in engineering content did improve significantly.

RESEARCH - PUNTAMBEKAR (2005)

- multiple means of scaffolding needed to support the learning of science concepts through middle school design-based activities
- learning occurs in the context of social interactions in which a more knowledgeable person guides a learner's emerging understanding (scaffolding)

RESEARCH - LEONARD AND DERRY (2011)

- simple science models alone (in this case, Newton's third law) were not sufficient to enable the design task.
- thoughtful scaffolding is required to use engineering to teach science concepts

RESEARCH - CRISMOND - 2001

- Experts viewed designs as malleable products while novices viewed products as immutable givens
- Non-expert designers did not use general science concepts to help with their redesigns.

RESEARCH IMPLICATIONS

- combined interactions of science, math, technology, and engineering in engineering design tasks is not understood
- sustained effect of elementary engineering program not understood
- development engineering milestones not well understood

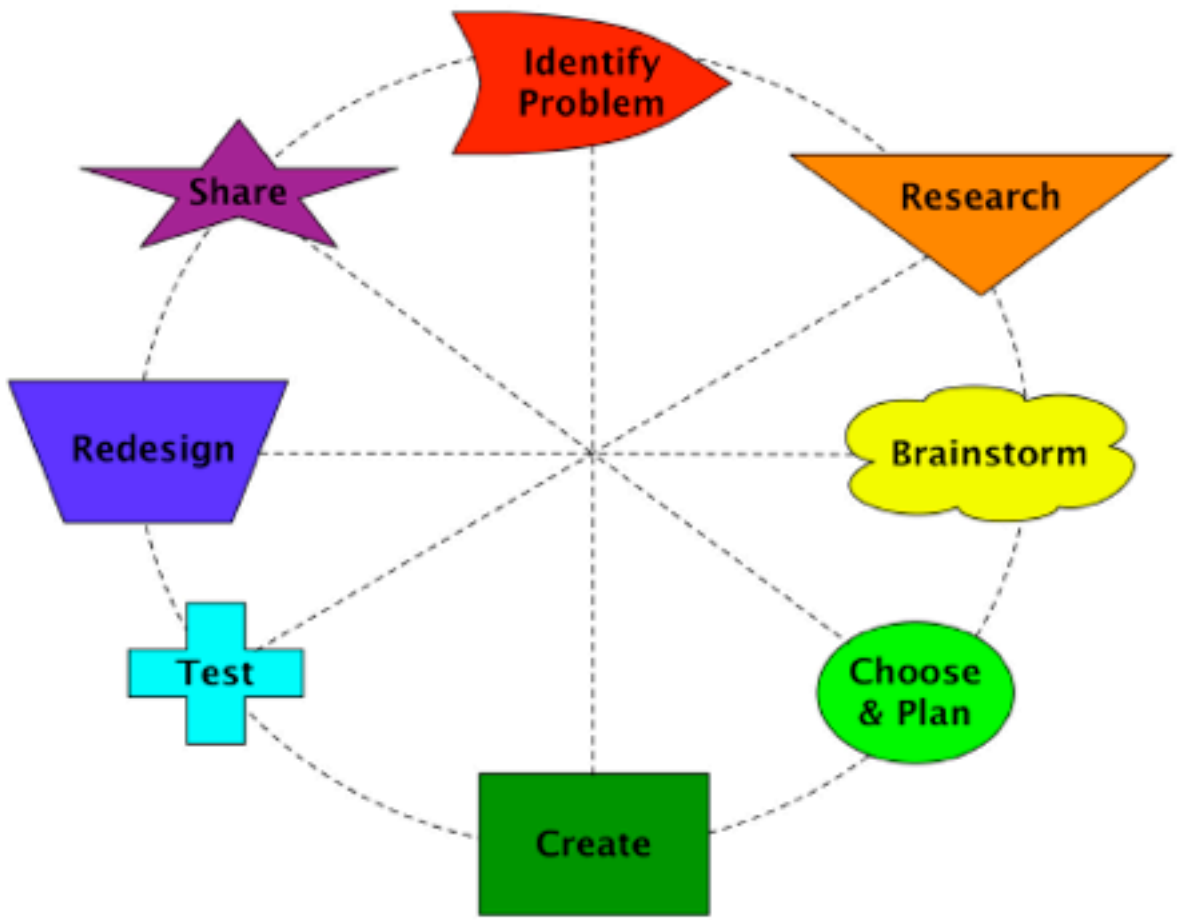
TEACHING ENGINEERING

- Open ended
- Coach rather than authority figure, not helping too much
- Scaffold as needed and teach prerequisite knowledge
- Collaborative
- Manager of process, materials, activities

ENGINEERING DEFINITION

Engineering requires applying content knowledge and cognitive processes to design, analyze, and troubleshoot complex systems to meet society's needs." (Brophy et al., 2008, p. 371) Implicit in that definition is creating models and predicting performance, which is what separates true engineering from trial and error methods.

Engineering Design Process



WHY ROBOTS?

- Engineering can be taught in many ways, why Lego Robots?
- Familiar, fun, fantasy
- They can be programmed, adds "life"
- Tech component built in
- Math, science, ELA as well

TAP CREATIVE PLAY

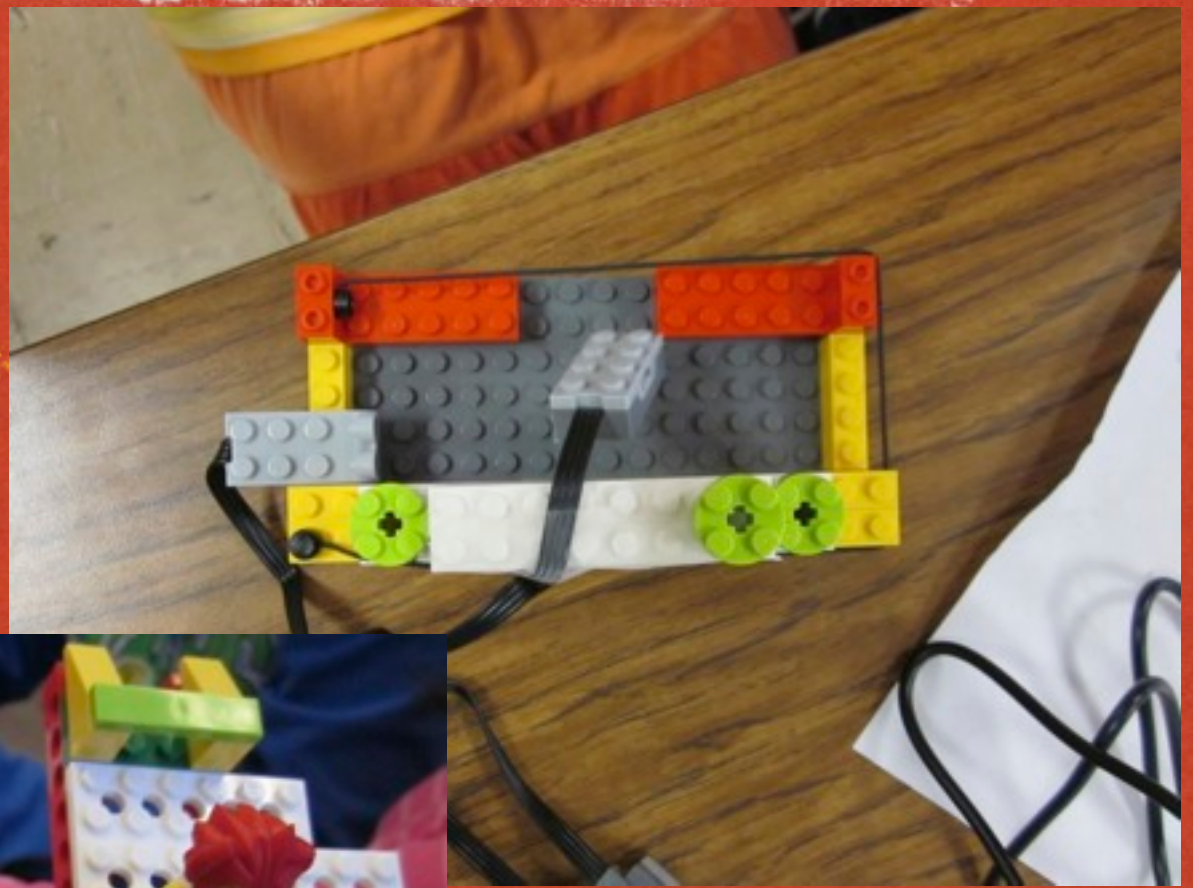
- Who is tapping into creative play? Are we?


Bell

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.

RESEARCH QUESTIONS

- Context: PK-6 Elementary Engineering Curriculum with open ended challenges for grades K, 2, 4, and 6. See kidsengineer.com for curriculum.
- What are the phases of engineering development in young students? (Case study)
- How do elementary schools support (or not support) engineering development in students? (Survey)
- Can a PK-6 program affect interest in STEM fields? (Survey, Interviews)



STUDENT VIDEO INTERVIEWS

- Done May/June 2011
- Had a flexible set of questions
- Done after recent robotics units
- Grades 4, 5, and 6
- Coded responses

HOW IS IT DIFFERENT?

[It's] Absolutely! [different from other schoolwork.] It's more interactive because mostly what we are doing in school is paperwork. With this you get to experiment, instead of just doing something, like math, you got a question, you figure it out. With this you can, change it up, experiment. *Grade 6 Boy 1*

It's fun and different in a different way. I just think it is more fun. The way you think - easier is some ways, harder in some ways. The way you think is more fun to think that way than the other way. *Grade 4 Boy Team 2*

QUOTES

I didn't think you would use all that math and science to build that robot. Grade 6 Girl 2

It's more fun [than usual schoolwork.] It's a lot different – sometimes mathematical. You have to think in a different way. This would make this, would make this, happen. Each step is connected. Grade 4 Boy Team

WHAT DID YOU LIKE ABOUT ROBOTICS?

What did you like about robotics?

24 Mentioned the project as fun
15 Got to build/hands on
8 Different than other school work/special/exciting
7 Liked the programming even though it was hard
5 Cool
4 It was satisfying/exciting getting things to work
2 Liked the trial and error
2 Had to learn to compromise, work together
2 Got to move around, not stay in seat

WHAT WAS HARD?

4 Being patient

2 Parts falling off

2 Programming

2 Programming sensors

WHAT DID YOU LEARN?

7 Programming

4 Math

3 Science/how things work

2 Technology

2 Engineering

2 Building

2 Distance = rate x time

RESEARCH - INTERVIEW RESULTS

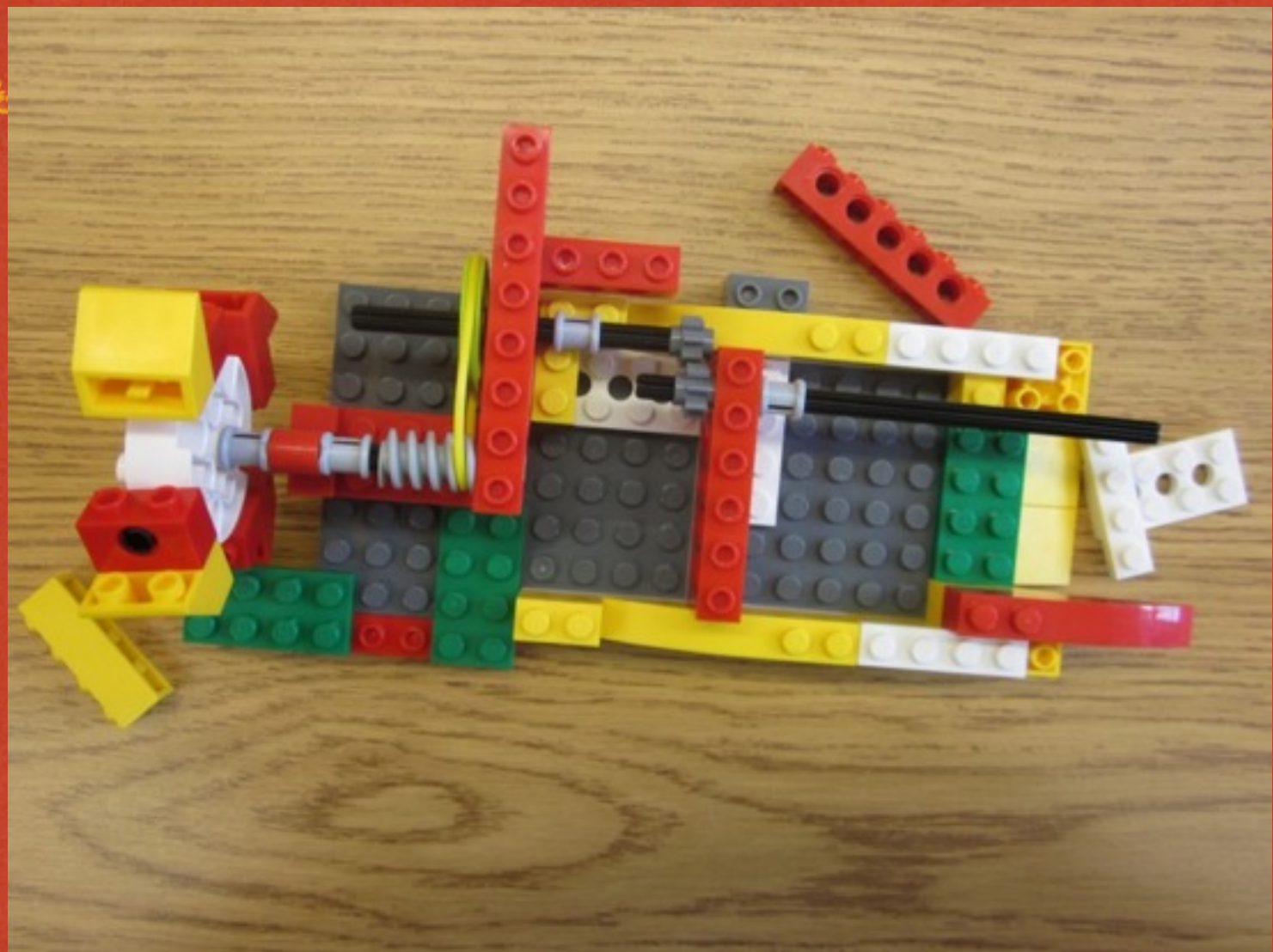
- See handout for more student quotes
- Student very aware of how they are being taught
- Prefer hands on activities and believe they learn better that way

CASE STUDY

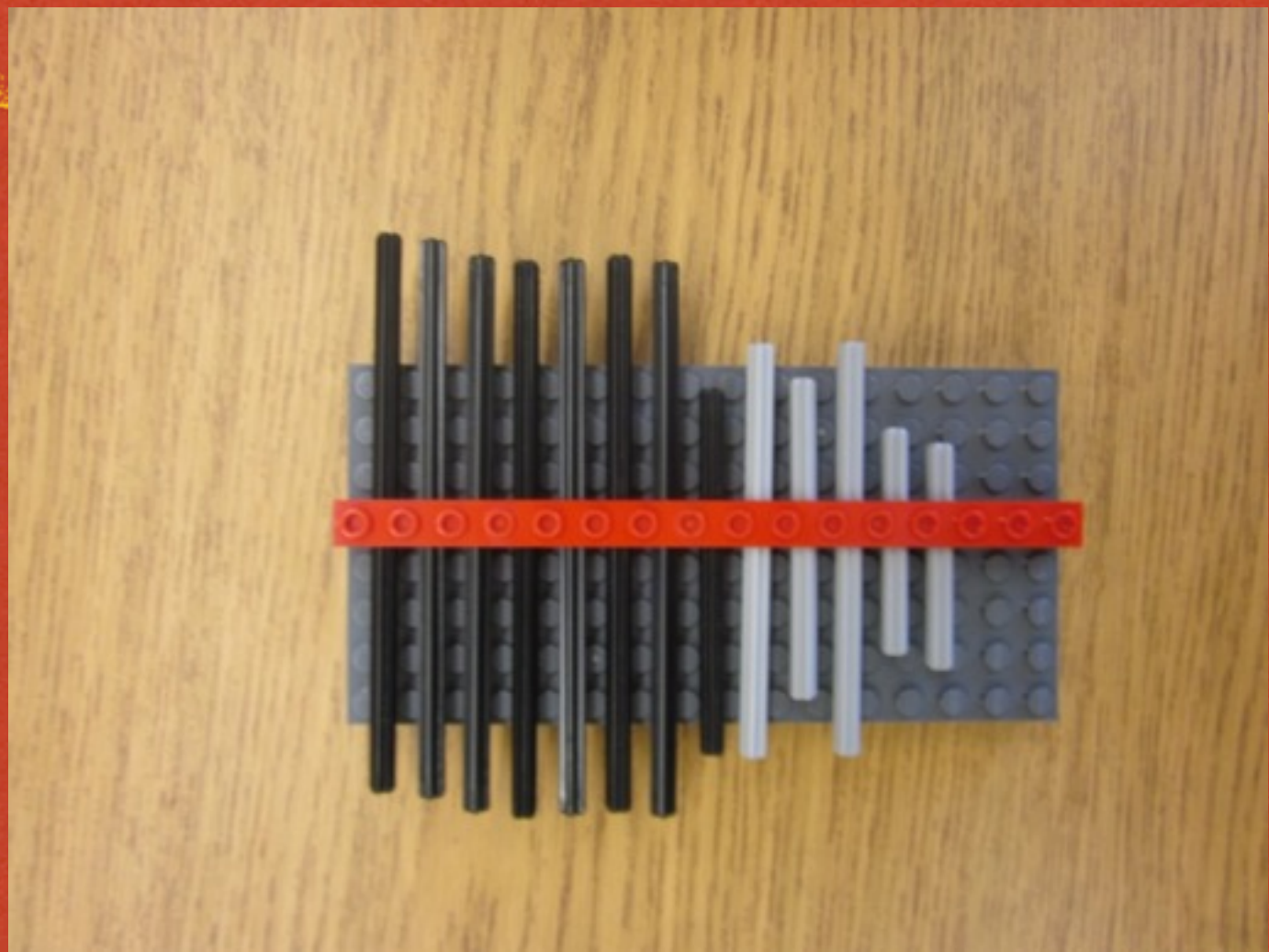
- Follow 8 current K kids for 7 years
- Yearly open ended challenge
- Videotape and photograph artifacts
- Learn more about the phases of engineering in young children

MERRY GO ROUND

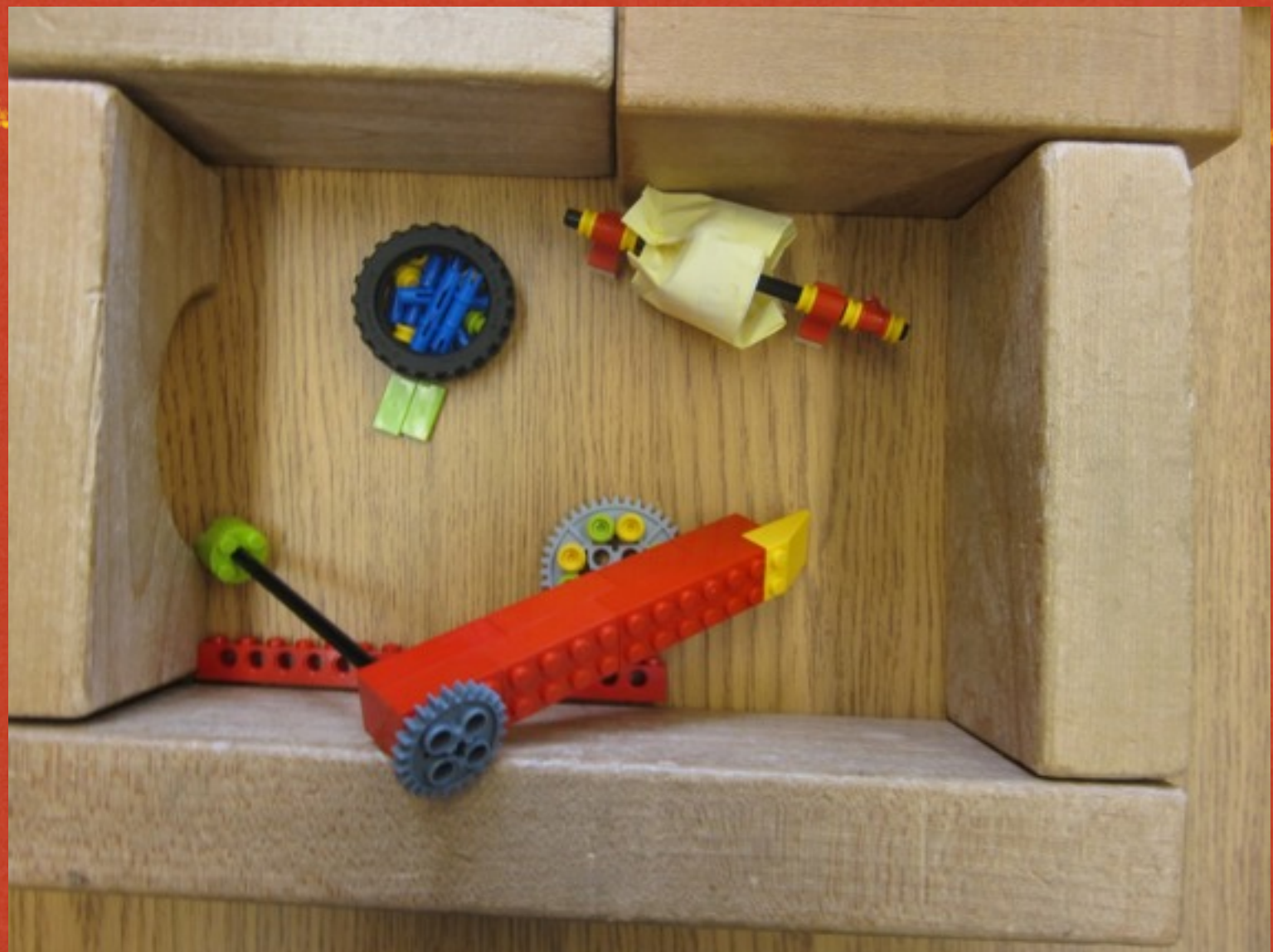
FERRIS WHEEL



SLIDE

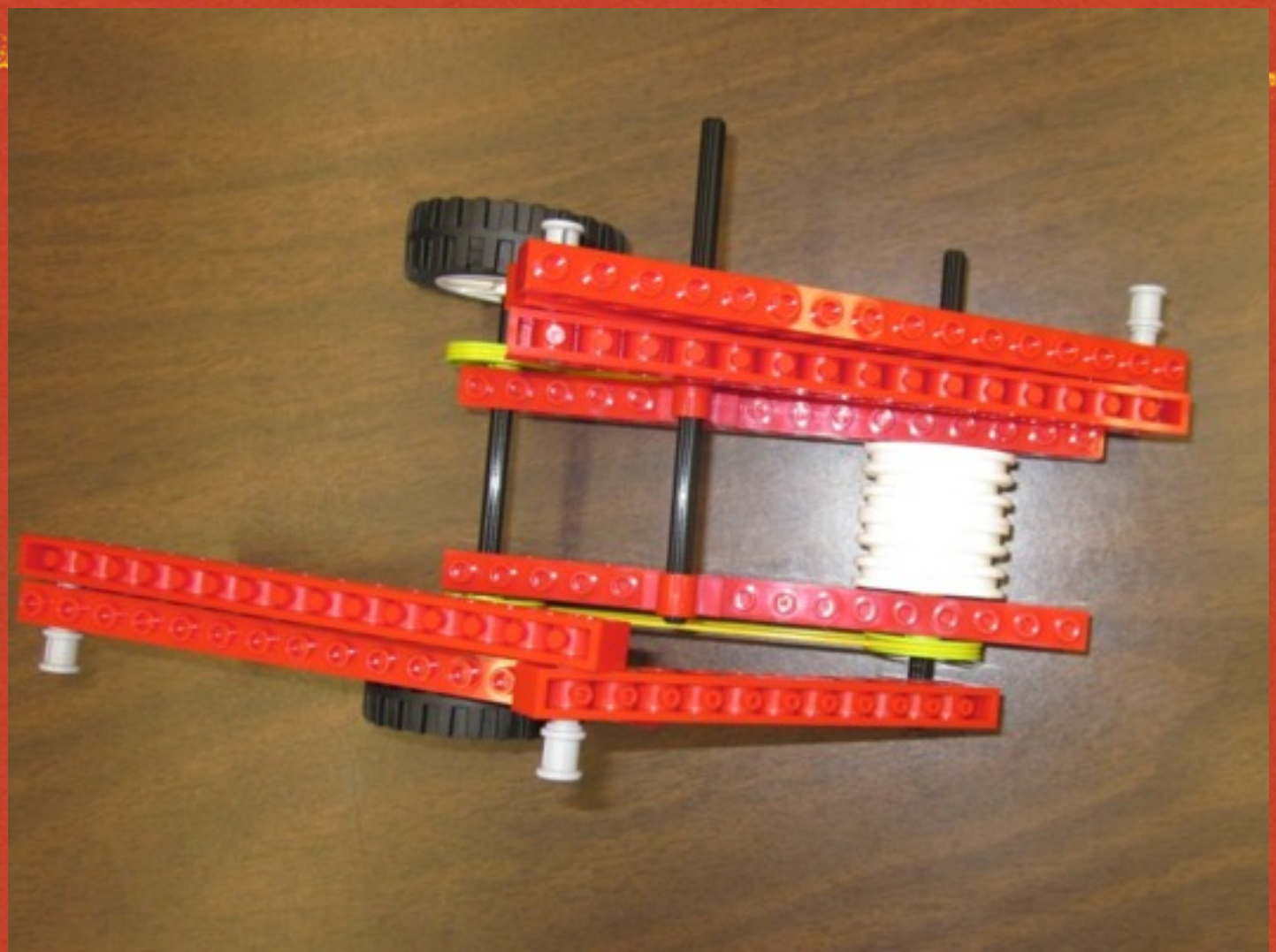


PARK

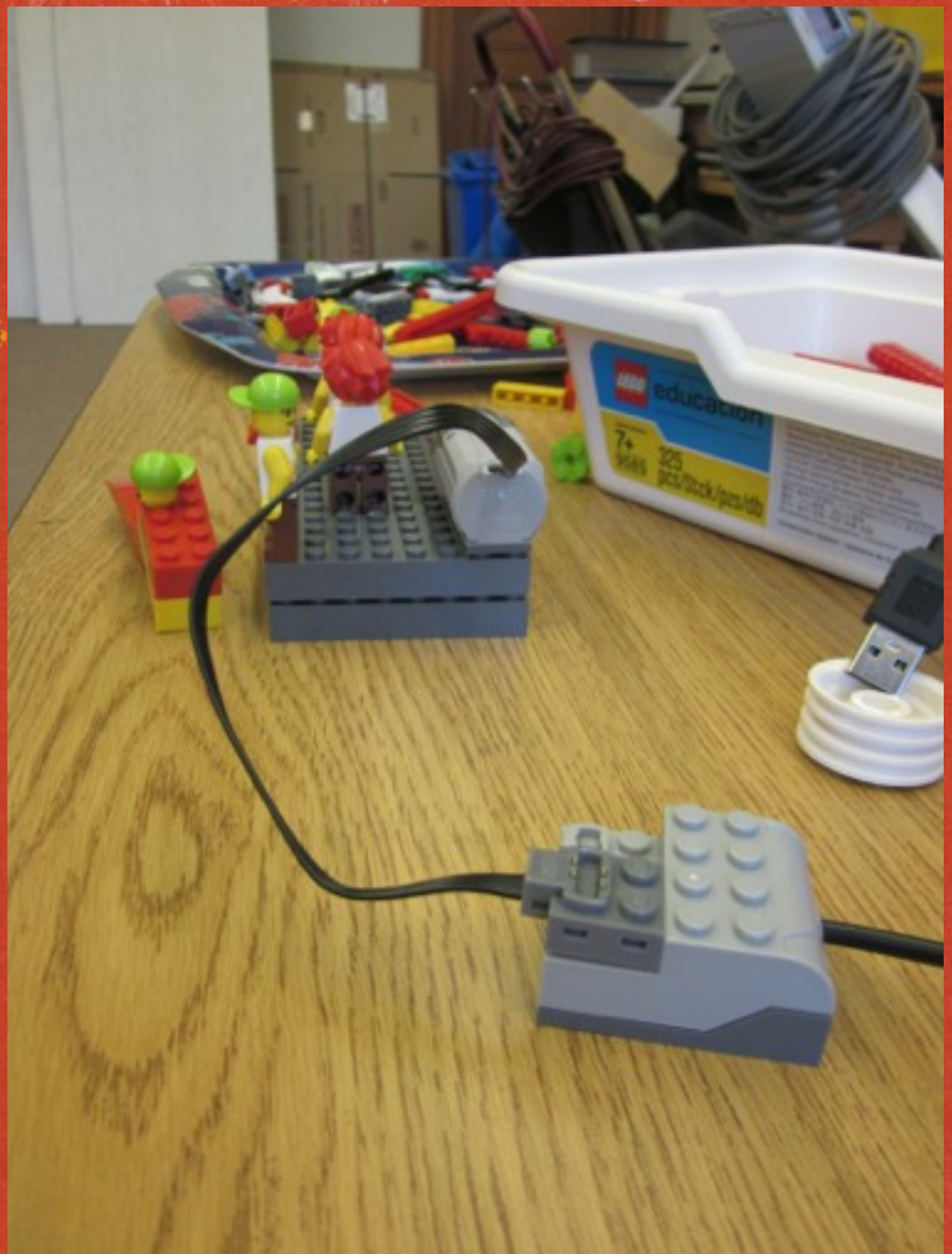


HORSE

RIDE WITH CRANE

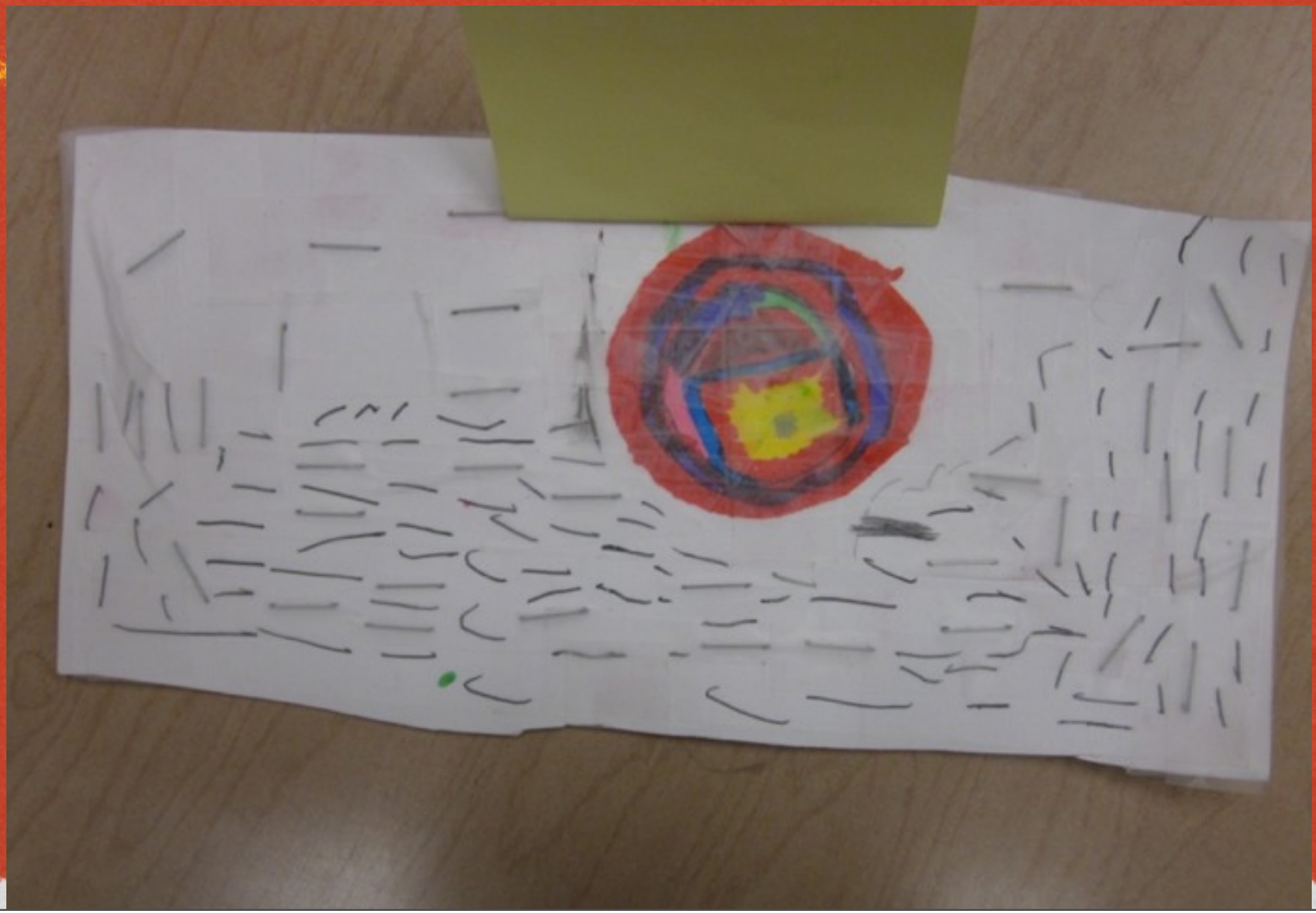


FUN HOUSE



RIDE LINE

MERRY GO ROUND



K OBSERVATIONS

- Use of LEGO in 7 of 9 cases
- Fine motor skills
- Many were eager to use computers even though not taught yet
- Self-talk
- Range of products

Grade 6 Robots – Pre-Survey

NAME [redacted] DATE 3-30-11

What is a robot? a robot is a Mechanical divice that you can Program to do different thing.

What is engineering? Engineering is a type of work that involves Mechanics

How much do you agree or disagree with these statements? Circle One.

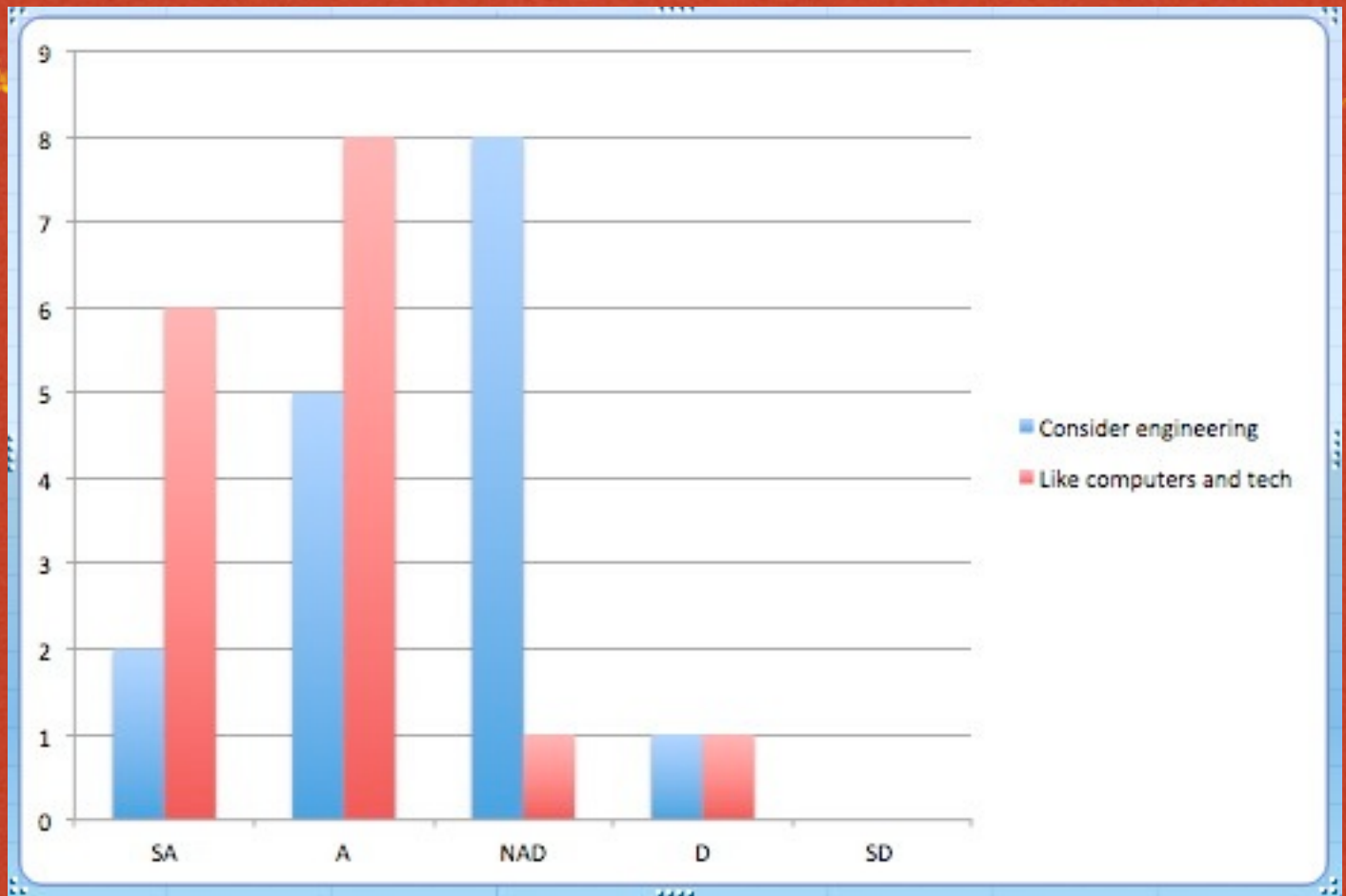
I want to be an engineer or scientists when I am older.

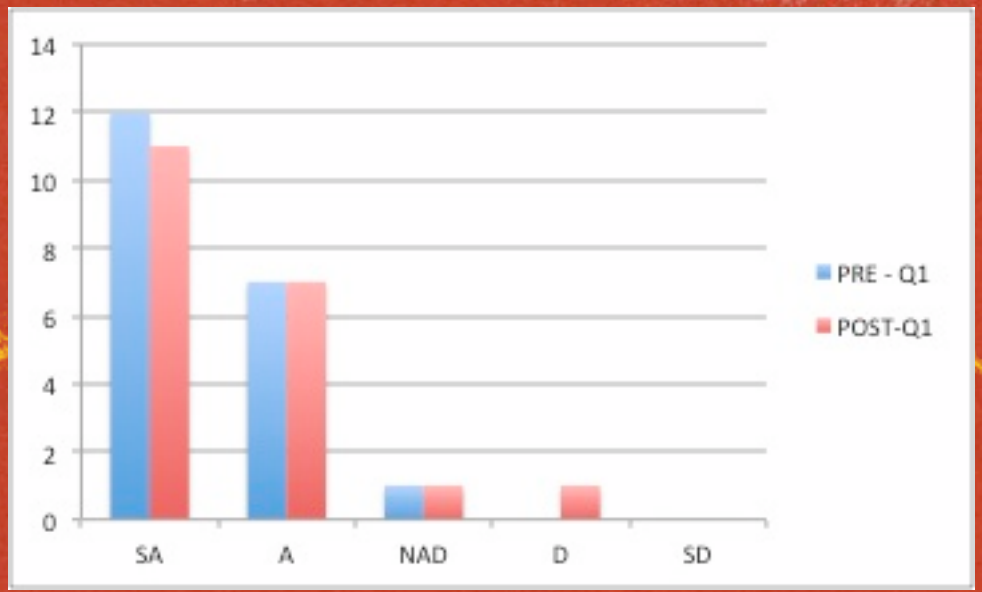
Strongly Agree Agree (Neither Agree or Disagree) Disagree Strongly Disagree

I like using computers and other technology.

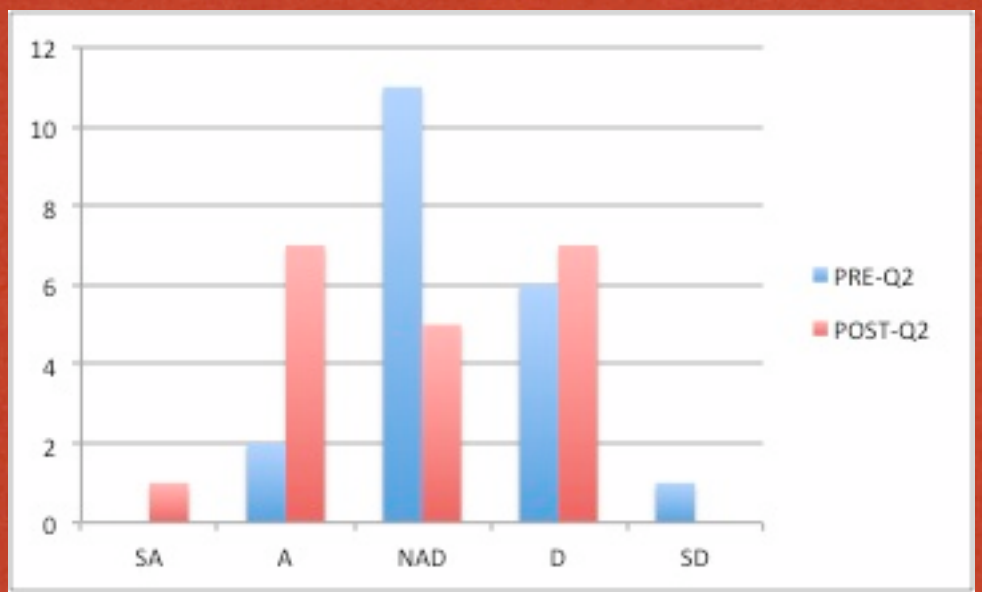
(Strongly Agree) Agree Neither Agree or Disagree Disagree Strongly Disagree

G6 2012 SURVEY





Like using computers and tech



Consider being engineer

n=20, p <.07/.02

Grade 6 2013 data

SEER GRANT

- Sustaining Elementary Engineering with Robotics
- 5 years, $1.3M
- Holyoke, Williamsburg, Chesterfield-Goshen, Amherst, Westhampton
- Partners: Hampshire Regional, UMASS, Tufts CEEO, LEGO Education, Sage Fox Associates

SEER GRANT 2

- Curriculum development and PD
- Explore the impact of robotics-based engineering education on K-6 children's interest, motivation, and self-efficacy.
- Investigate K-6 students' understanding of core robotics, engineering, math, and science concepts using the engineering curriculum.
- Explore how the teachers' characteristics (e.g., content knowledge, interest in STEM) and their actual implementation of the engineering curriculum affect student achievement.

TEACHER INTERVIEW

PROJECT IDEAS

- Marble runs
- Recycled creations
- A Chair for Bear (see Tufts CEEO)
- Robotics
- Bridges
- Propeller/Balloon cars

ROBOTICS COSTS ($21-$37/ STUDENT)

BeeBots (PK-K) 10 for $800

Lego WeDo Getting Started Package - $1708.95
$575 Resource Set 12 pack

Lego NXT 12 Pack $3,225.95
SW Site license $339.95
$1152 12 pack resource set

PD $800/day

Resources

- jheffernan@hr-k12.org
- Kids Engineer - http://www.kidsengineer.com/
- Engineering is Elementary - http://legacy.mos.org/eie/
- Teach Engineering - http://www.teachengineering.org/
- Tufts CEEO - http://ceeo.tufts.edu/