# Evaluating a Design-Based Learning Curriculum in Terms of Students' Science Reasoning Gains in a High-Needs Setting

Eli M. Silk & Christian D. Schunn
Learning Research & Development Center, University of Pittsburgh

Mari Strand Cary
Department of Psychology, Carnegie Mellon University

NARST 2007 Annual Meeting, New Orleans, LA

# Design-Based Learning (DBL)

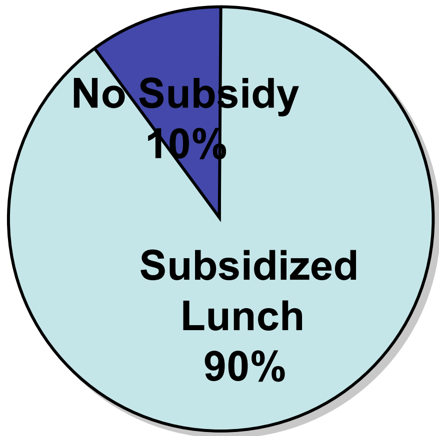
- Important features
  - Engineering design of an artifact
    - Designed around the solution to a personal, everyday need
    - Design project is the central activity
    - Immersive and extended
  - Science is the goal
    - Focused on core, standards-based content

# Evidence of Design-for-Science

- Effective for teaching *science reasoning*
  - Kolodner et al., 2003
    - Experiment design, running experiments, analyzing results
  - Fortus et al., 2005
    - 'Designerly' problem-solving skills
- Why?
  - Externalizing ideas (Roth, 2001)
  - Motivating (Seiler, 2001)
  - Sense-making (Benenson, 2001)

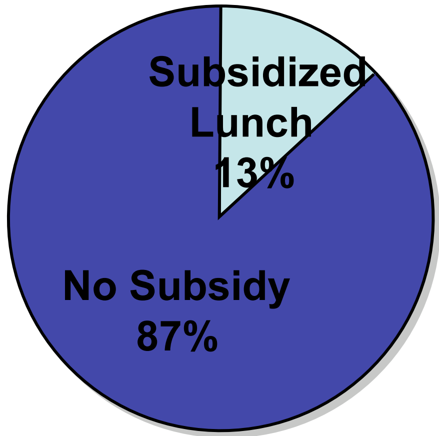
# The Effect of Setting

- New curricula often tested in ideal settings
  - Fair test of efficacy for high needs settings?




- Time to master CVS (Li, Klahr, & Siler, 2006)
  - 7-8x increase for high-needs setting

- DBL in high-needs settings?
  - Majority in middle/upper class settings
    - Kolodner et al. 2003 - middle-income communities and affluent communities
    - Fortus et al. 2005 - “blue-collar families”
  - More research needed in highest needs schools

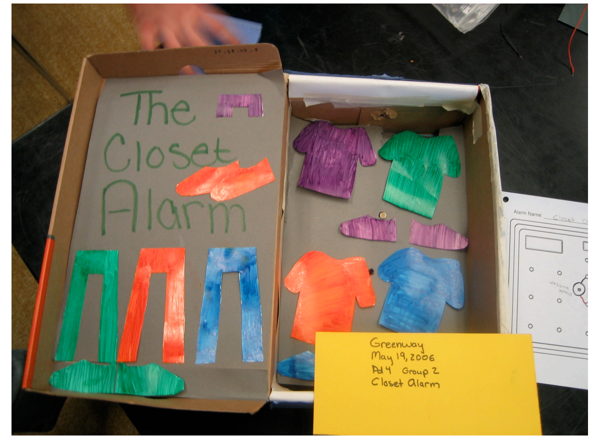


# Assessment

- In high-needs schools, paper-based multiple-choice tests are important
  - Individual
  - Abstract and content-free
  - Higher reading demands
- Disaggregate to examine achievement of traditionally-disadvantaged groups
  - Low-SES students
  - Minority students (African-Americans)
  - Females

# The Curriculum Context

## *The Electrical Alarm System*





- The Design Cycle
  - Needs analysis
  - Criteria development
  - Prototype design
- *Ritualized activities* highlight and reinforce important science ideas and processes
  - Subsystem breakdown
  - Presentations of ideas
  - Teacher modeling
- Content Goals
  - Properties of electricity and electrical principles relating to voltage, current, and resistance in different components and circuit designs
- Science Reasoning Goals
  - Systematically test ideas for improving design
  - Draw valid conclusions from own and others' data about how electricity works

# Research Questions

- Is engineering design a viable means for teaching abstract science reasoning?
  - In high-needs urban settings?
  - Are gains detectable with paper-based, multiple-choice assessments?
  - To what extent are traditionally-disadvantaged students improving?

# Methods

- The Electrical Alarm System, 8 week electronics unit
- 2 teachers, 8 eighth grade sections, 170* students
- Mid-size, high-needs urban district
  - 83% qualify for government subsidized lunch (low-SES)
  - 73% African-American
- Pre/Post assessment of science reasoning
  - **Reduced test** (6 items) - Classroom Test of Science Reasoning (Lawson, 1978)
    - Facilitate comparisons to alternative curricula
      - Inquiry curriculum (3 yrs) & Textbook curriculum (3 yrs)
  - **Full test** (13 items) - additional items to increase reliability

# Sample Assessment Question

## Drawing conclusions from data

Twenty fruit flies are placed in each of four glass tubes. The tubes are sealed. Tubes I and II are partially covered with black paper; Tubes III and IV are not covered. The tubes are placed as shown. Then they are exposed to orange light for five minutes. The number of flies in the uncovered part of each tube is shown in the drawing.

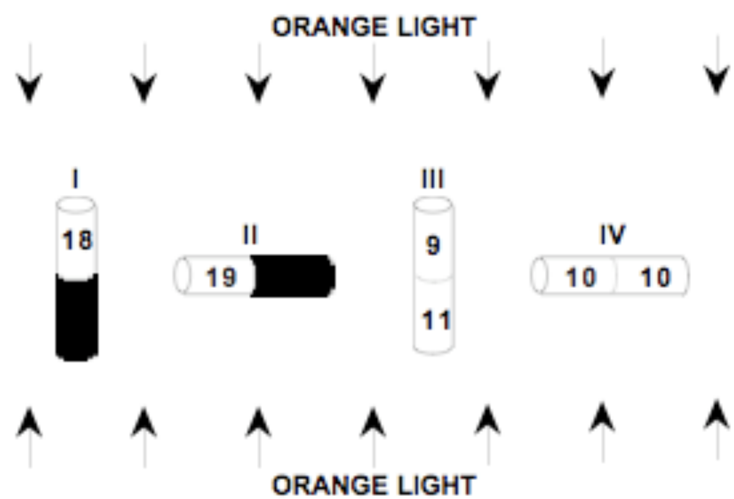
These data show that these flies respond to (respond means move to or away from):

a. Orange light but not gravity

b. Gravity but not orange light

c. Both orange light and gravity

d. Neither orange light nor gravity

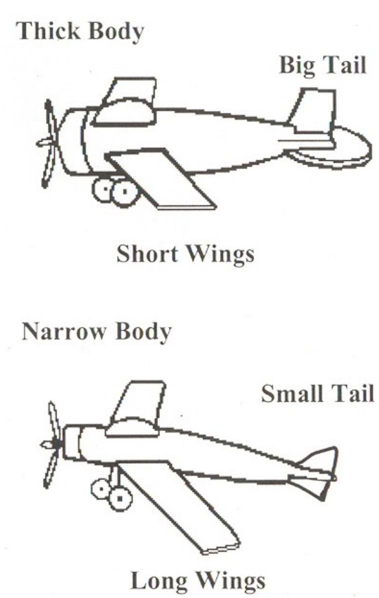


# Sample Assessment Question

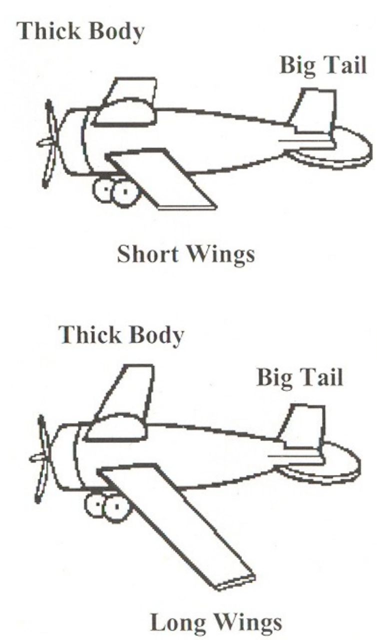
## Control of Variables Strategy (CVS)

A group of engineers wants to design a model airplane that can fly as fast as possible. They can change the BODY (narrow or thick), the WINGS (long or short), and the TAIL (big or small). If they want to find out whether the length of the WINGS makes a difference, which set of planes should they build?

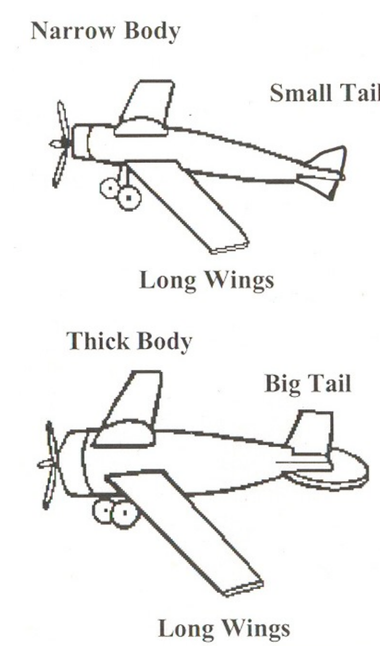
A




B

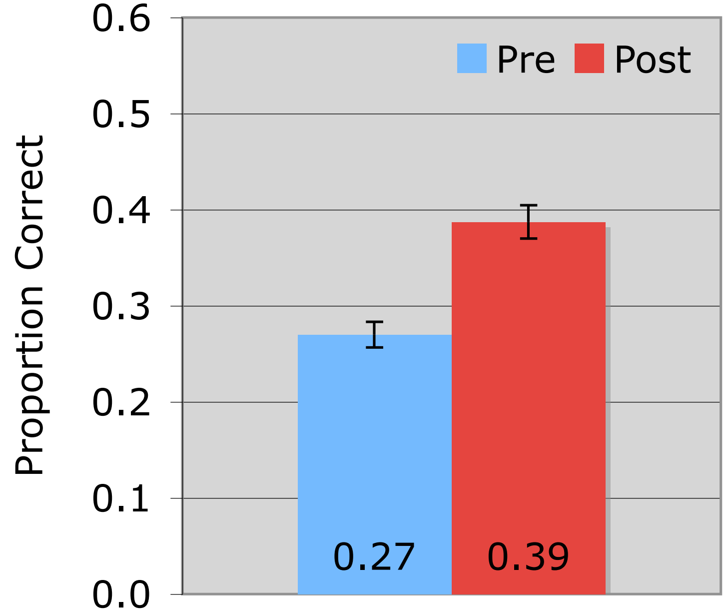



C



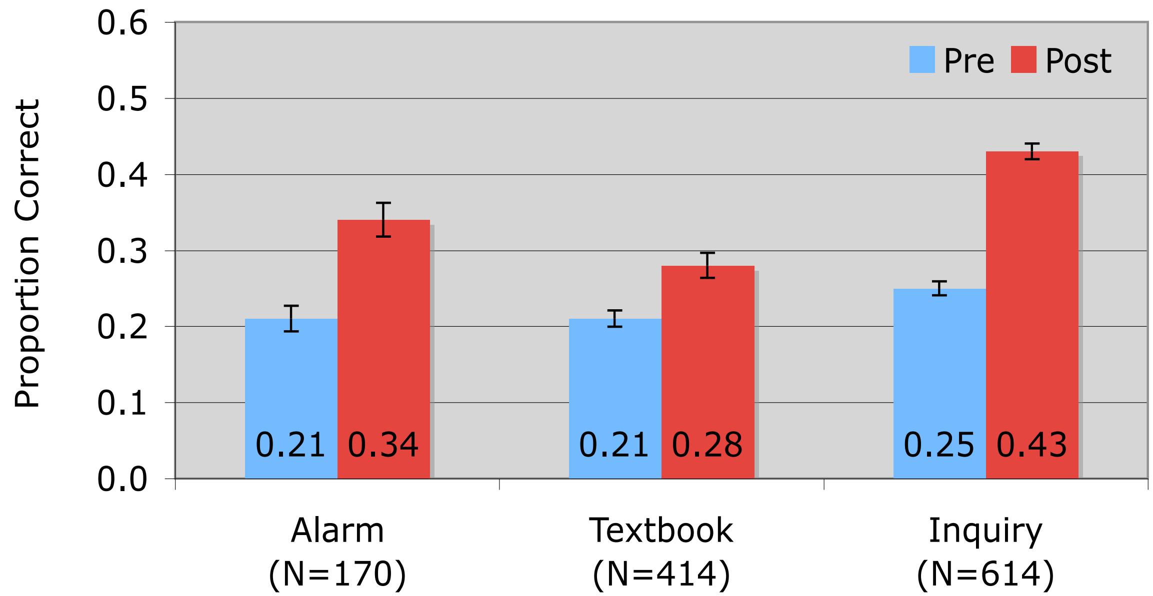
# Were there gains in science reasoning?
## Improvement from Pre to Post (13 items)

- There was a significant improvement from pre-test to post-test
  - Mann-Whitney test ($U = 2292.5$, $p < .001$)
  - Note: students near chance at pre (middle of 8th grade!)
  - Effect size = 0.67
    - Big or small for 8 weeks?



# How *large* are the gains we observed?
## Comparison to Full 3-Year Curricula

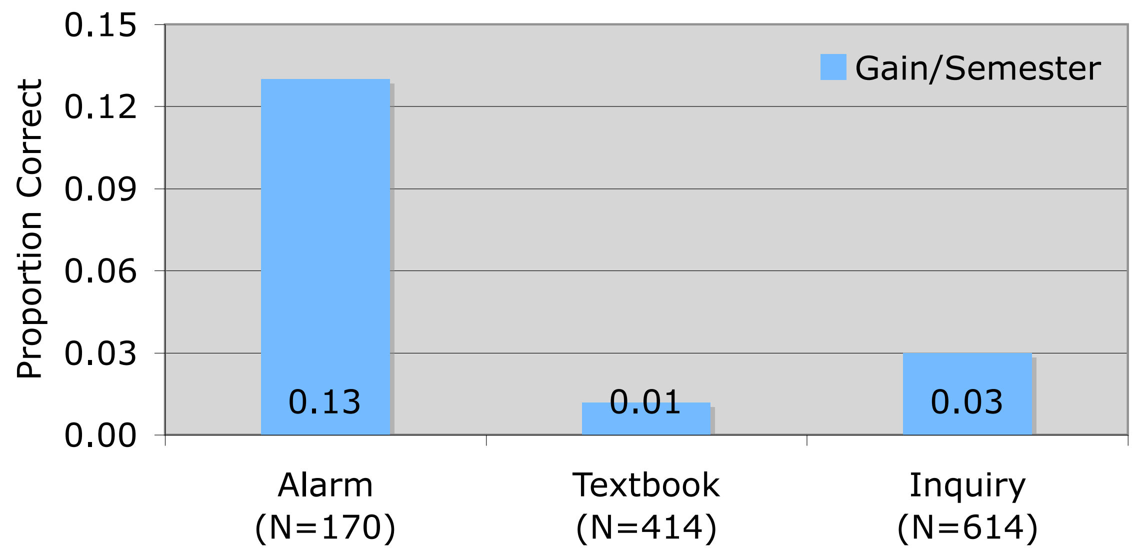
- Effect Sizes
  - Alarm = 0.58
  - Textbook = 0.34
  - Inquiry = 0.81




- Larger gains than a 3-year textbook curriculum
- Smaller gains than a 3-year inquiry curriculum

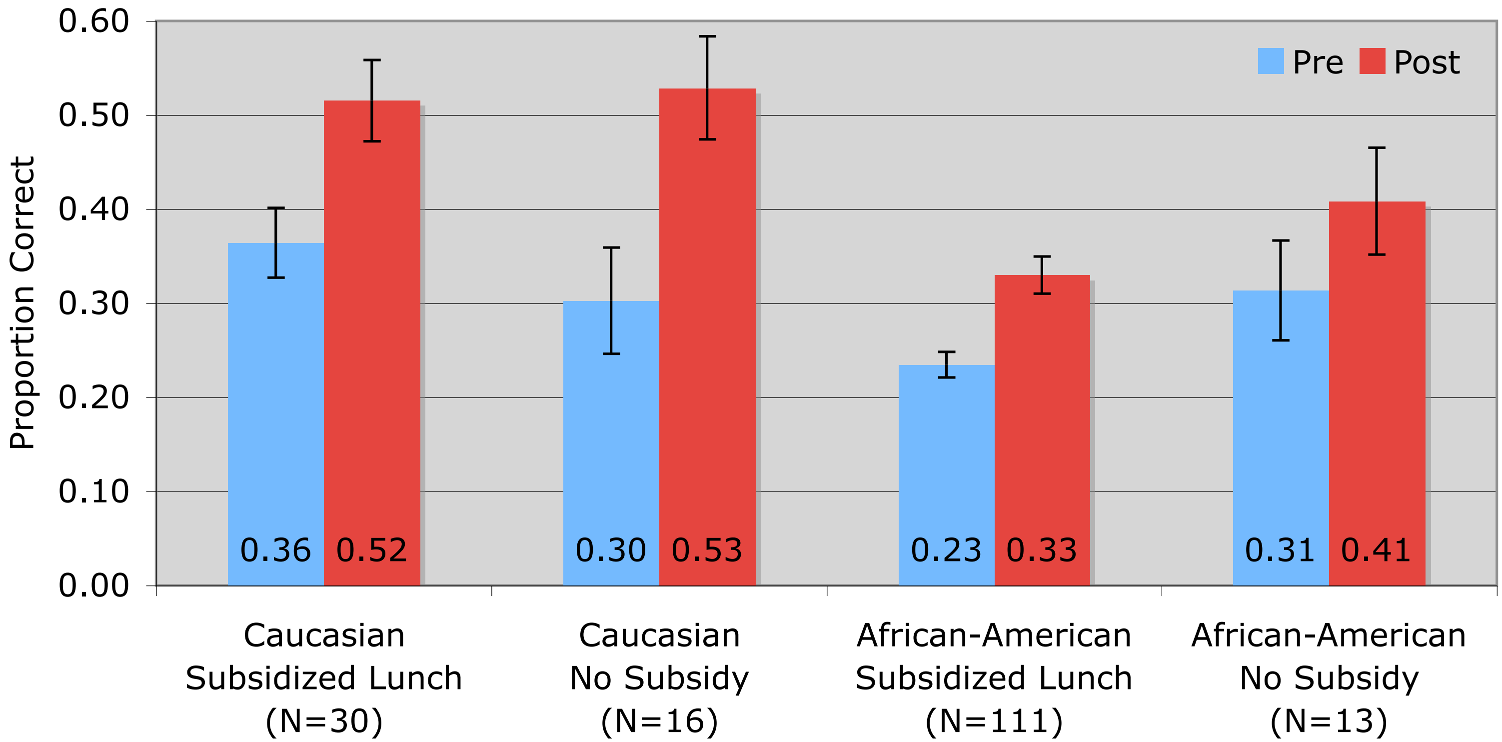
# How *large* are the gains we observed?
## Comparison to Full 3-Year Curricula

- Gain/Semester
  - Alarm = 0.13
  - Inquiry = 0.03
  - Textbook = 0.01



# Relative Influence of Student Factors

- Multiple regression model predicting post-test score
  - Pre-test score (b = .36 ***)
  - Special Ed (b = -.23 ***)
  - African-American (b = -.26 ***)
  - Subsidized Lunch (ns)
  - Gender (ns)



# Accounting for Reading Differences

- Second multiple regression model with the addition of standardized reading score
  - Pre-test score (b = .29 ***)
  - African-American (b = -.15 **)
  - Subsidized Lunch (ns)
  - Gender (ns)
  - Special Ed (ns)
  - Standardized reading score (b = .34 ***)
- Lower performance of special education students may be better explained by differences in reading ability

# DBL Support of Science Reasoning

- Students are improving in abstract science reasoning
  - Even in a very high-needs setting
  - Evident in paper-based, multiple-choice assessments
- Traditional achievement gaps are not decreasing
  - Reading and prior achievement are major obstacles
  - Much work to be done in identifying the particular needs and challenges of African-American students
- DBL is not a magic bullet (like other reform curricula)
  - Favorable results compared to other 3 year middle school curricula
  - Potential for better results if done more often

# Thank You

Eli M. Silk
esilk@pitt.edu

# References


Benenson, G. (2001). The unrealized potential of everyday technology as a context for learning. *Journal of Research in Science Teaching, 38*(7), pp. 730-745.

Fortus, D., Krajcik, J., Dershimer, R. C., Marx, R. W., & Mamlok-Naaman, R. (2005). Design-based science and real-world problem-solving. *International Journal of Science Education, 27*(7), pp. 855-879.

Kolodner, J. L., Gray, J. T., & Fasse, B. B. (2003). Promoting transfer through case-based reasoning: Rituals and practices in Learning by Design™ classrooms. *Cognitive Science Quarterly, 3*, pp. 183-232.

Lawson, A. E. (1978). The development and validation of a classroom test of formal reasoning. *Journal of Research in Science Teaching, 15*(1), pp. 11-24.

Li, J., Klahr, D., & Siler, S. (2006). What lies beneath the science achievement gap: The challenges of aligning science instruction with standards and test. *Science Educator, 15*(1), pp. 1-12.

Roth, W.-M. (2001). Learning science through technological design. *Journal of Research in Science Teaching, 38*(7), pp. 768-790.

Seiler, G. (2001). Reversing the “standard” direction: Science emerging from the lives of African American students. *Journal of Research in Science Teaching, 38*(9), pp. 1000-1014.