Comprehending

THE RELATIONSHIP BETWEEN READING, MATH, & CS LEARNING OUTCOMES

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Some factors linked to success in a first CS course:

Math & Science

Number of Previous Programming Languages

Time Management

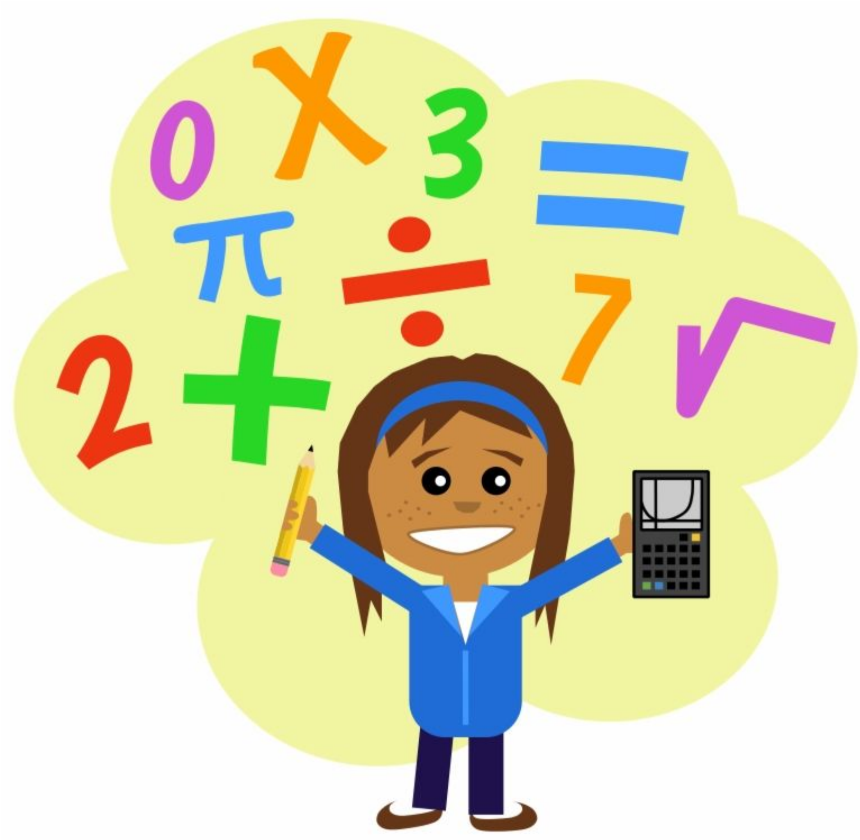
Intrinsic Motivation

How many of those skills did you have when you were 9-10 years old?

CS/CT instruction is spreading to increasingly younger students.

Image from Robotics Learning Online

We need to understand how reading & math influence CS learning.



Images from adazing.com & vippng.com

Outline

Motivation

Related Work

Theoretical Framework

Study Design

Results

Most studies on factors predicting CS performance are at the university-level.

Performance in Other Subjects

Math

(Pea et al, 1983; Byrne et al, 2001; Wilson et al, 2001)

Science

(Byrne et al, 2001)

Most studies on factors predicting CS performance are at the university-level.

Performance in Other Subjects	Prior experience
Math *Science*	*Exposure to computers* *(Bergin et al, 2005)* *Number of programming languages* *(Hagan et al, 2000)* *Mental models of programming* *(Weidenbeck et al, 2004)*

Most studies on factors predicting CS performance are at the university-level.

Performance in Other Subjects

Math
Science

Prior experience

Exposure to computers
Number of programming languages
Mental models of programming

Belief systems

Intrinsic motivation
Self-efficacy
Students' perception of their understanding
(Bergin et al, 2005)
Comfort level
(Wilson et al, 2001)

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Performance in Other Subjects

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Cognitive & metacognitive skills

Problem-solving (Goold et al, 2000)
Visual-spatial skills (Tolhurst et al, 2006)
Resource management strategies (Bergin et al, 2005)
Algorithmic articulation style (Cutts et al, 2006)

Most K-12 studies: Informal settings with middle and high school students

Performance in Other Subjects

Math

(Grover et al, 2016; Lewis et al, 2012; Qian et al, 2016)

English

(Grover et al, 2016; Qian et al, 2016)

Prior experience

Exposure to computers

Extracurricular technology activities

(Grover et al, 2016)

~~Belief systems~~

~~Cognitive & metacognitive skills~~

We are among the few that study factors for CS learning in elementary schools of different performance levels.

Performance in Other Subjects
- *Math proficiency*
- *Reading comprehension*
- *English*

Prior experience
- *Exposure to computers*
- *Extracurricular technology activities*

~~Belief systems~~

~~Cognitive & metacognitive skills~~

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Neo-Piagetian Theories explain how children learn.

Piaget (1976)

Biological maturation

& interaction with the environment

Neo-Piagetian Theories explain how children learn.

Case (1978) *Individual factors*	Fischer (1980) *Environmental & social factors*
Piaget (1976) *Biological maturation* *& interaction with the environment*	

Neo-Piagetian Theories explain how children learn.

Commons (2008)

Simpler □ more complex tasks

Case (1978)

Individual factors

Fischer (1980)

Environmental & social factors

Piaget (1976)

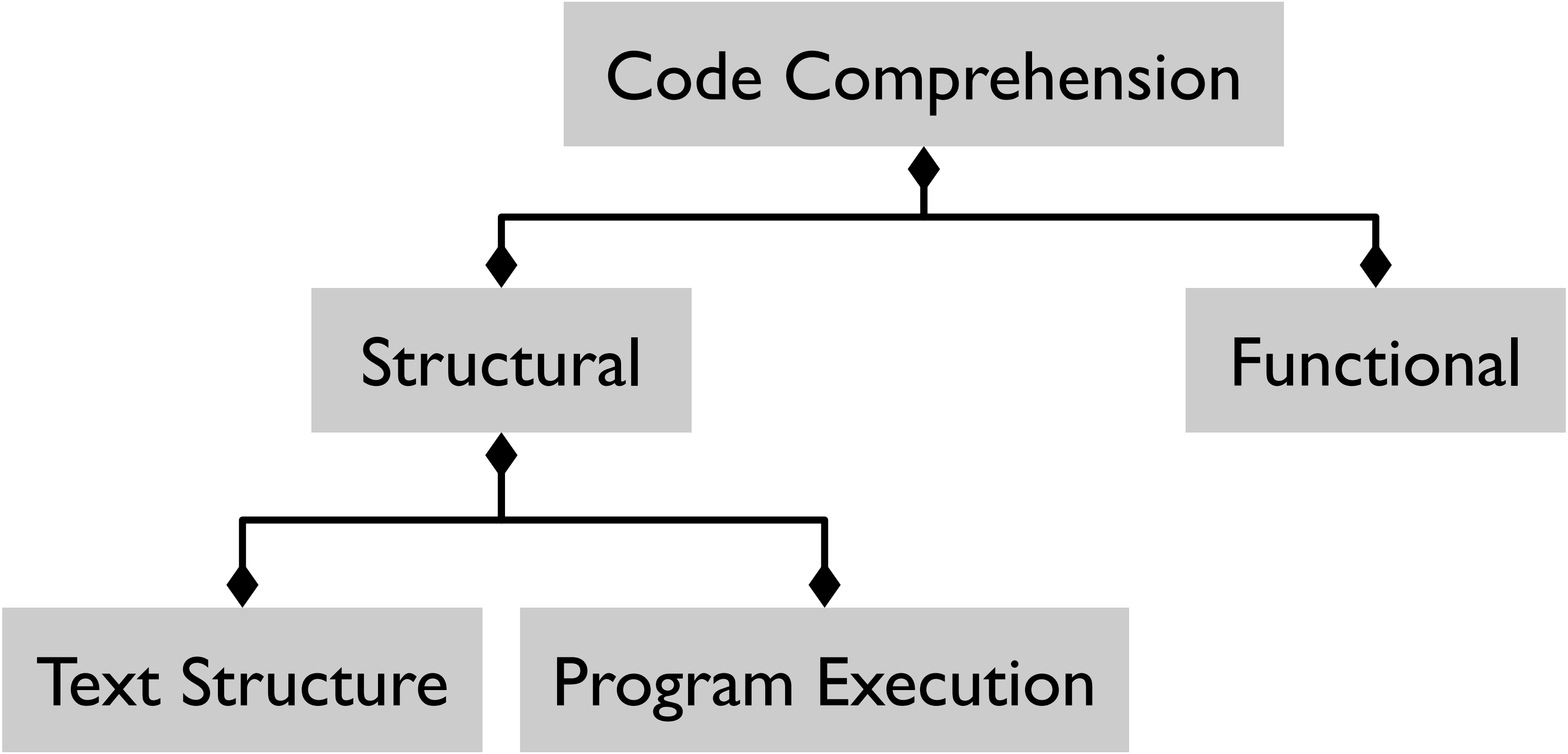
Biological maturation
& interaction with the environment.

Neo-Piagetian Theories explain how children learn.

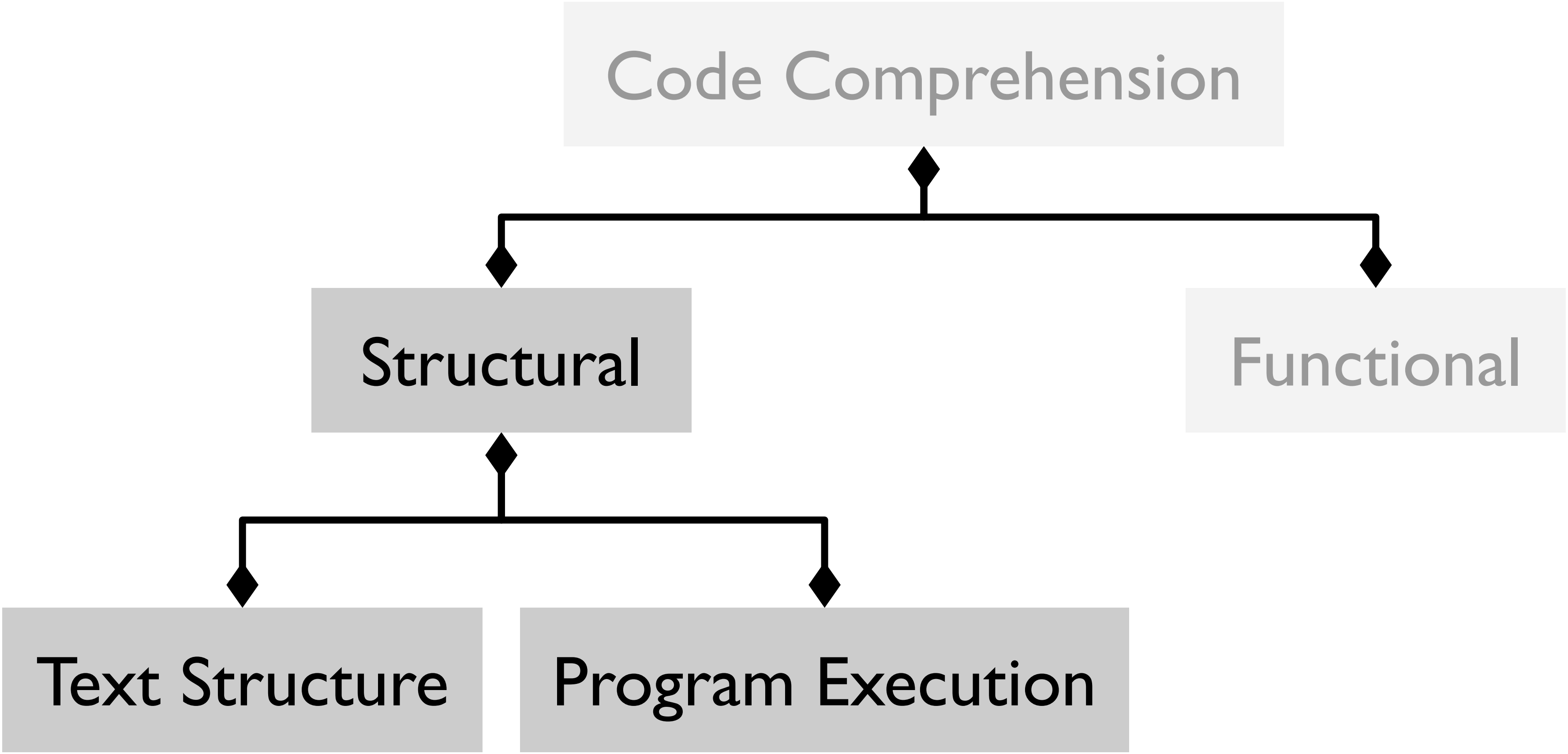
Commons (2008) *Simpler More complex tasks*	**Halford (1993)** *Existing mental models*
Case (1978) *Individual factors*	Fischer (1980) *Environmental & social factors*

Piaget (1976)
Biological maturation
& interaction with the environment.

Schulte's Block Model explains the types of code comprehension.



Schulte's Block Model explains the types of code comprehension.



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Students learned events, sequence & loops.

296 students (ages 9-10) who were:

from 1 high-, 2 mid-, & 1 low-performing schools in a large, urban school district

taught 3 computational thinking modules in Scratch: events, sequence, & loops
given assessments at the end of each module

Assessments were given after each module.

Guided by the Evidence-Centered Design framework

Domain analysis: CS K-12 framework & K-8 trajectories

(Rich et al, 2017-19)

Evaluated by researchers & practitioners for face validity

Cronbach's alpha for internal reliability

Assessment scores were compared across reading & math proficiency levels.

Split into reading & math proficiency levels: significantly below, below, at, or above grade level

ANOVA F-test for reading & math influence:

p-value: probability that results are by chance

η^2 effect size: how much variance in a dependent variable is associated with the independent variable

Type 3 Sum of Squares for imbalance

Tukey-Kramer Post Hoc for pairwise comparisons

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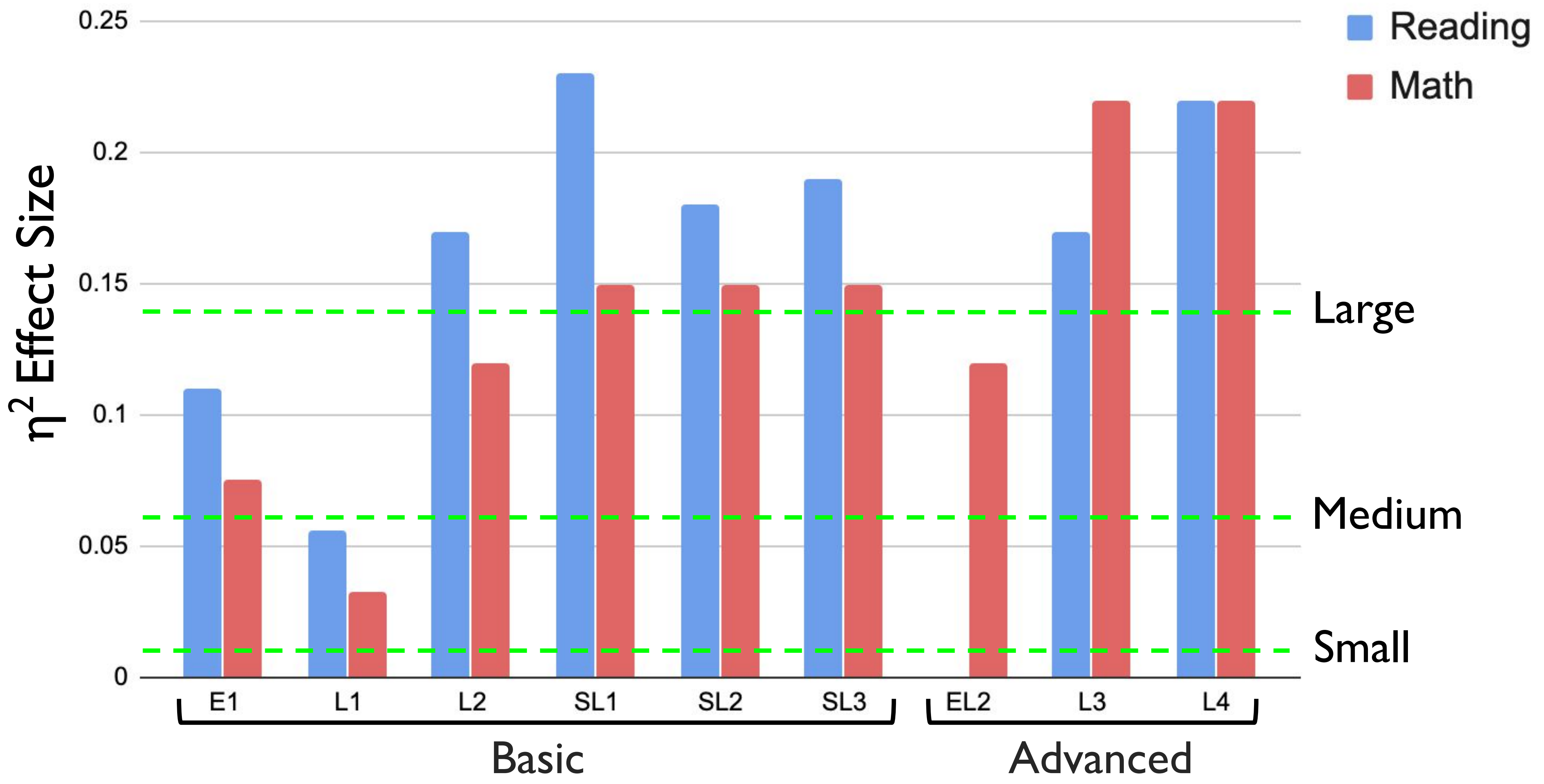
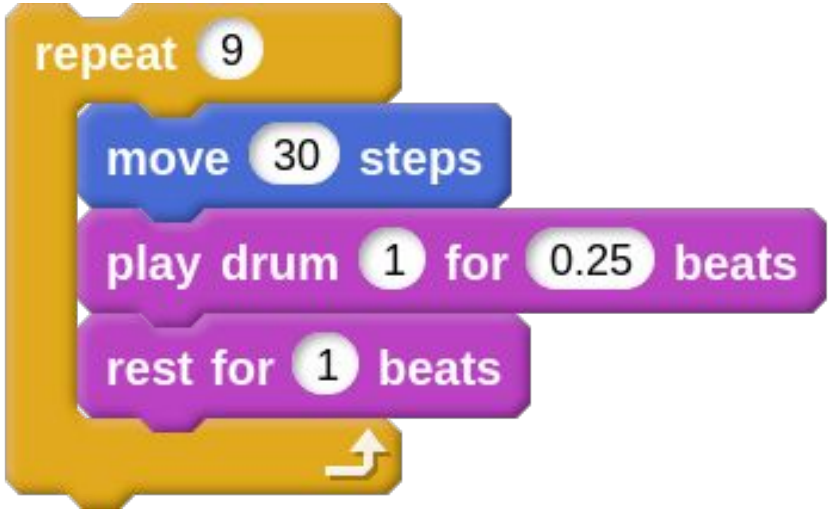
Reading was more associated with basic questions, while math was more associated with advanced questions.



Reading had a stronger association with text surface questions.

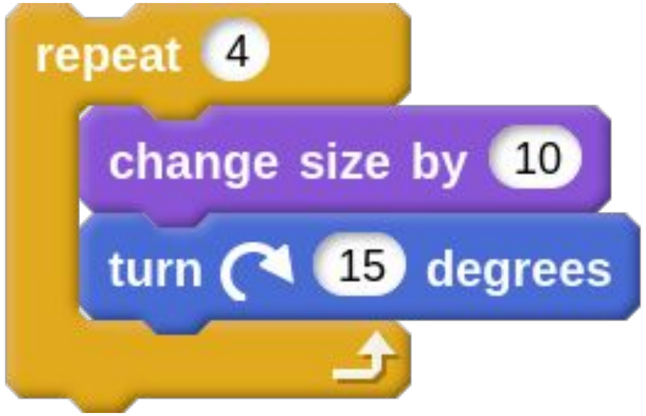
Repeat Iteration Count Question:

How many times will the loop repeat?

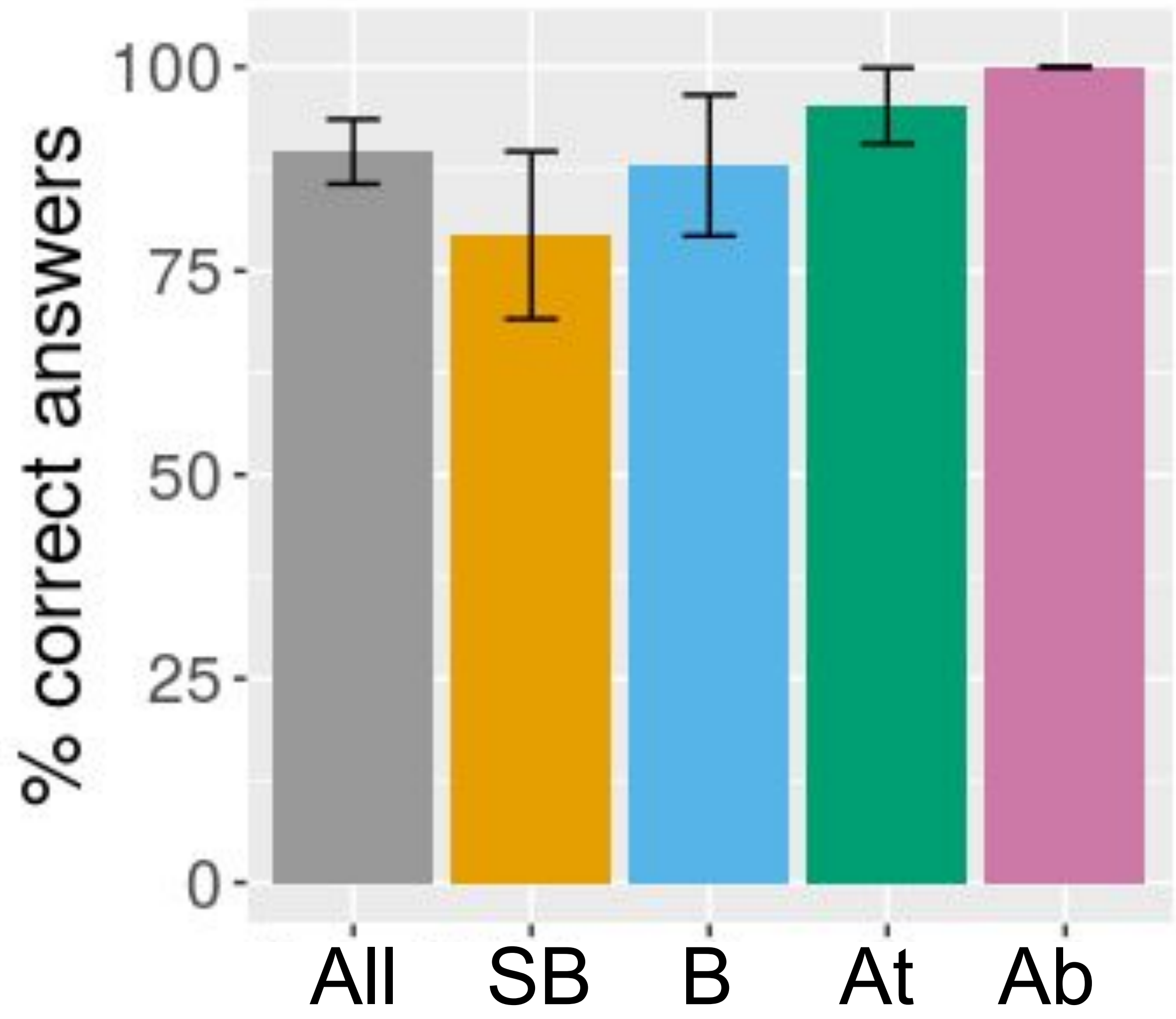


Loop Unrolling Question:

Which script does the same thing as the loop?



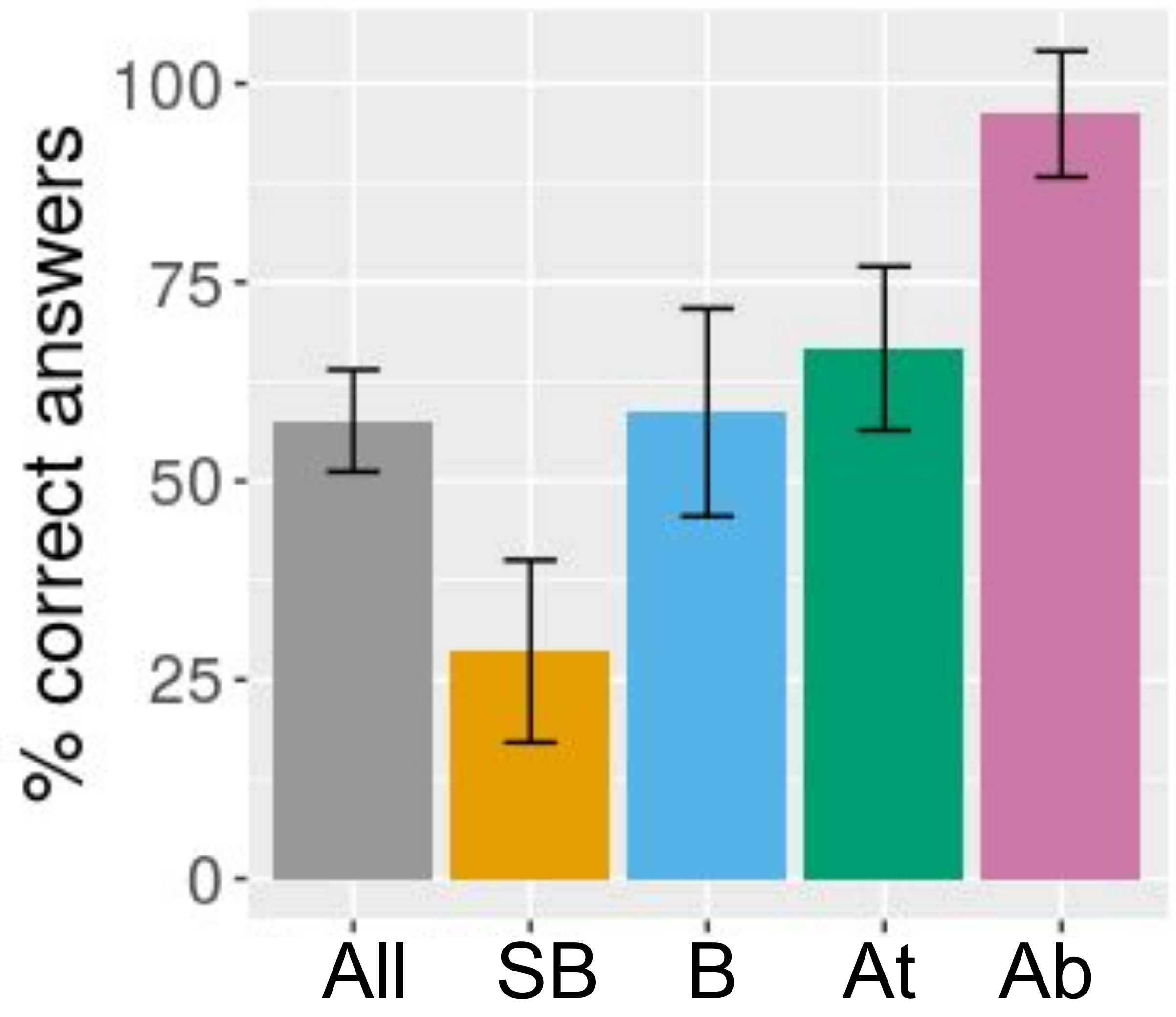
Repeat Iteration Count: Students reading below grade level significantly underperformed.



Students above grade level outperform students who are below grade level to any extent.

Students at grade level outperform students who are significantly below grade level.

Loop Unrolling: Students reading above grade level outperformed all other students.



Most students have a shallow understanding of loops.

Students reading at grade level still struggled → Challenges extend beyond reading comprehension.

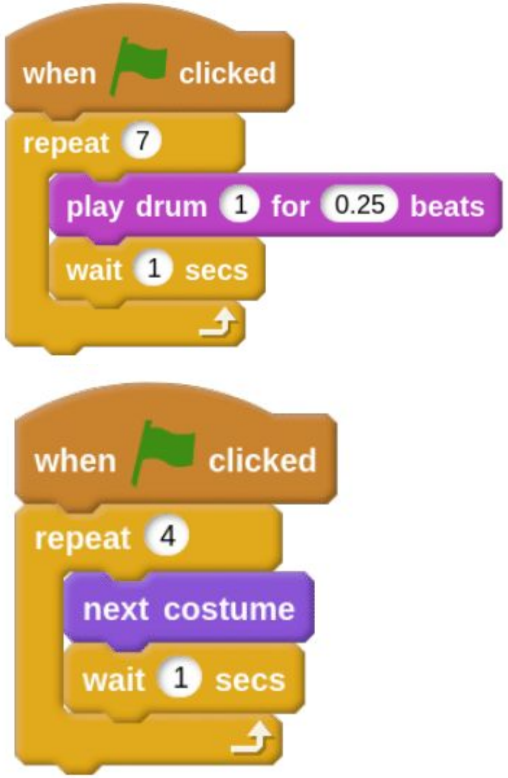
Math had a stronger association with program execution questions.

Parallelism Question:

Distinguish between Pico's sequential & Giga's parallel code

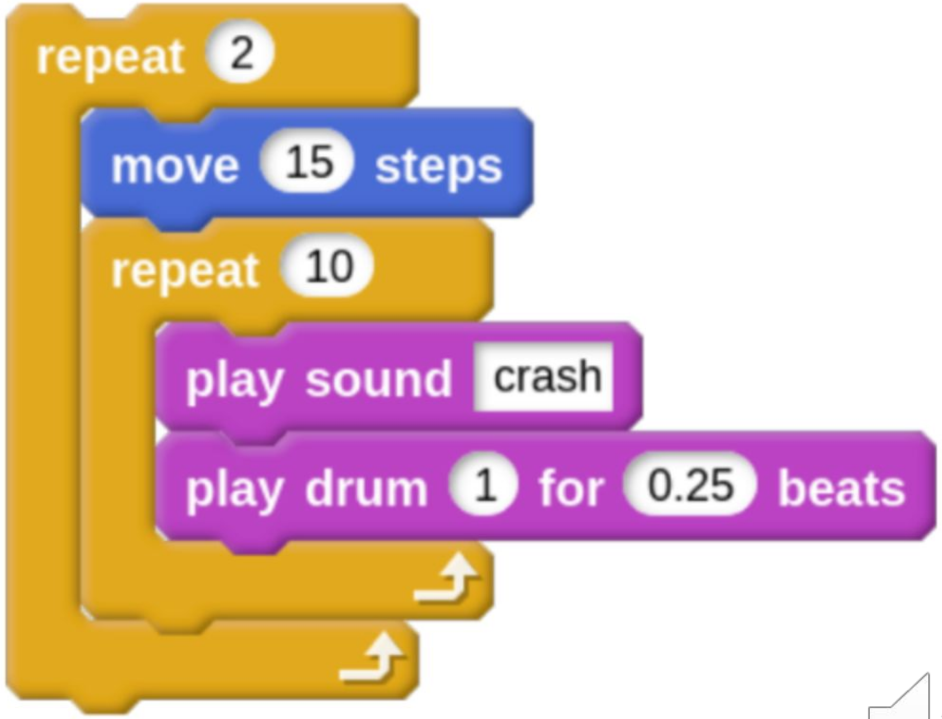
Pico's Code

Giga's Code

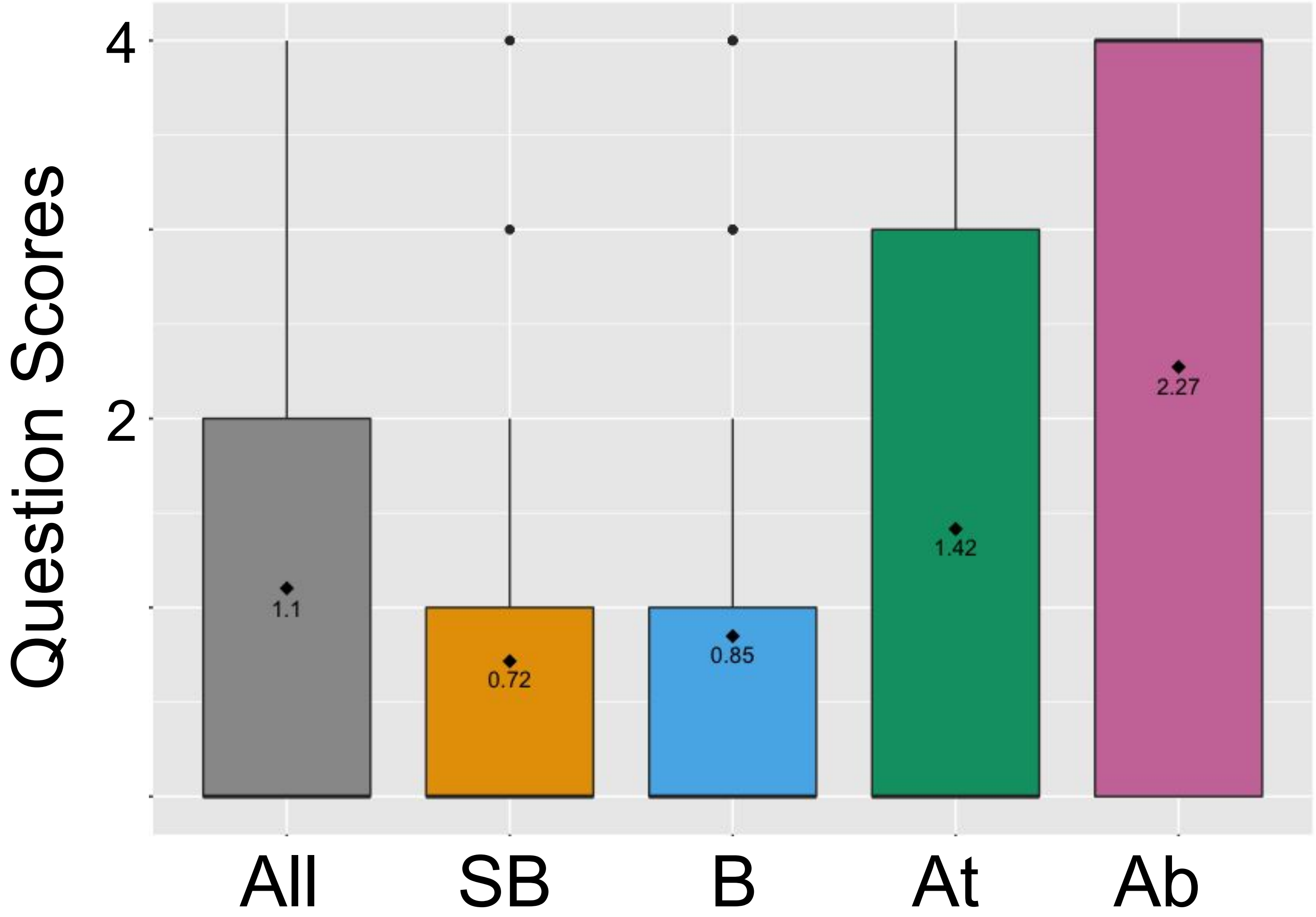


Nested Loops Question:

How many times will the "crash" sound play?



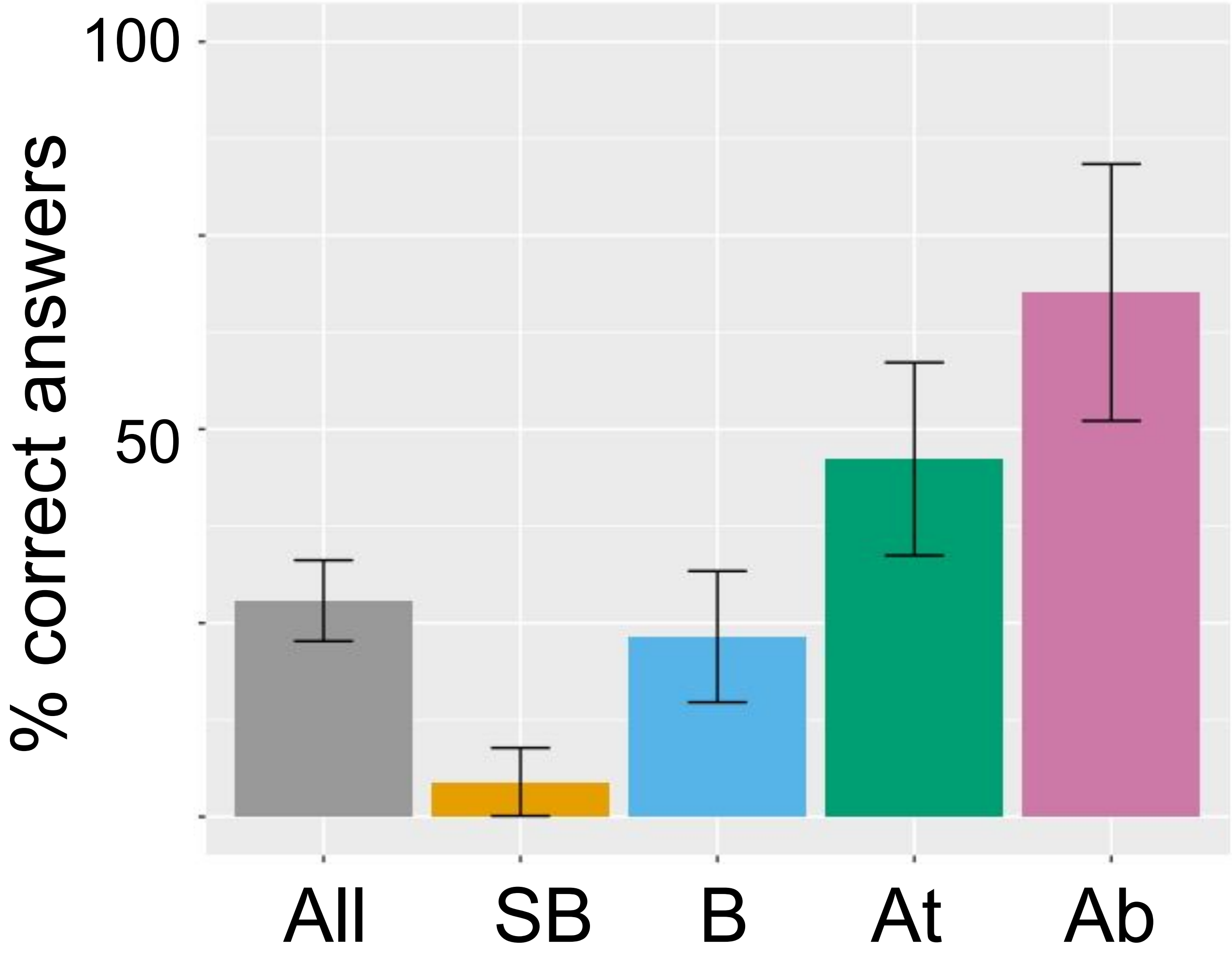
Parallelism: Students who were below grade level in math significantly underperformed.



Overall, students struggled with parallelism.

Better math proficiency may help with understanding parallelism, even without direct calculations.

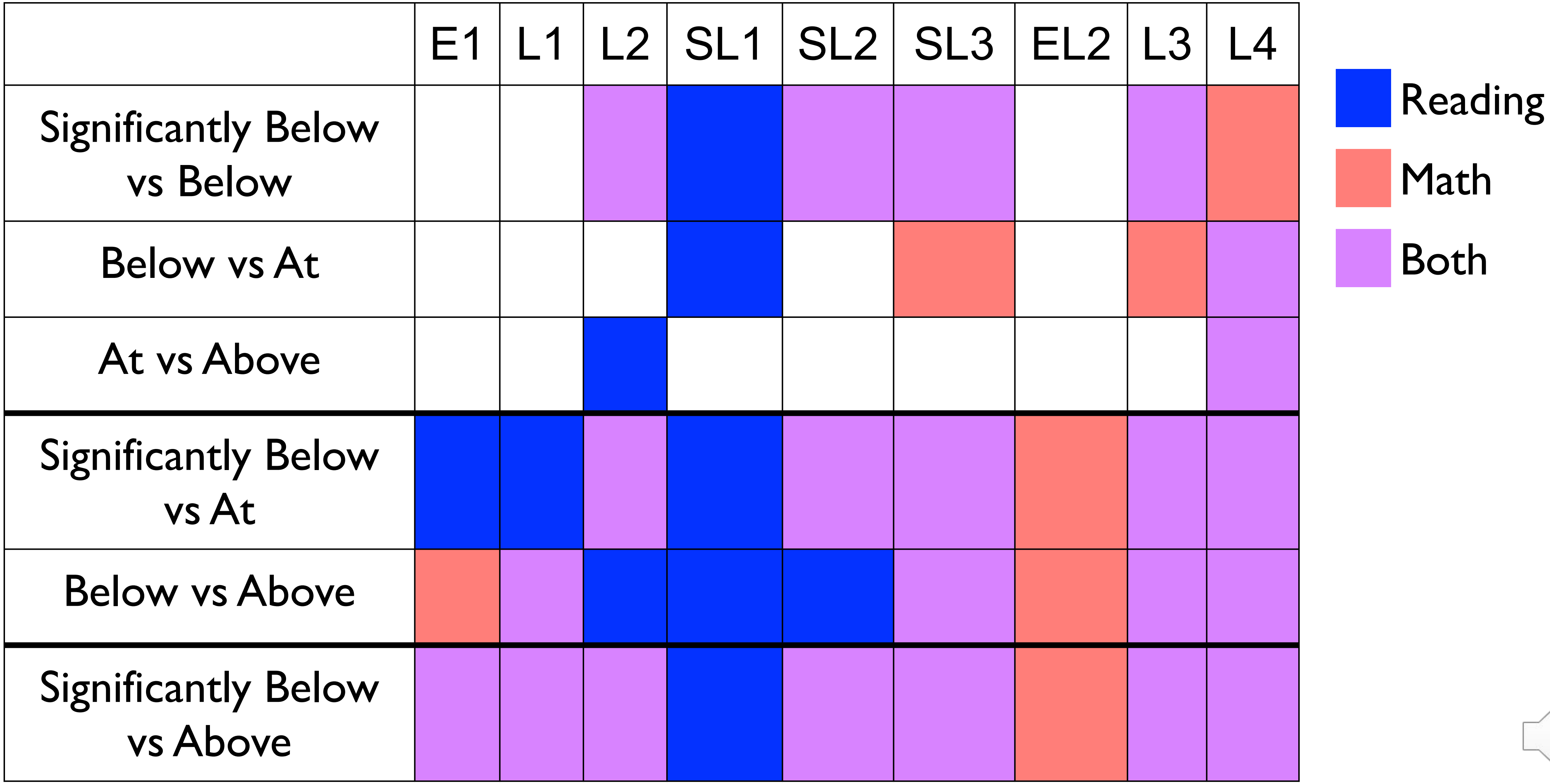
Nested Loops: Students who were below grade level in math significantly underperformed.



Nested loops were not explicitly taught.

Understanding loops may be related to understanding multiplication.

Performance gaps between proficiency levels reinforce the need for improvement in instruction.



Understanding barriers to programming guides the development of solutions.

We need to decouple CS/CT learning from reading & math.

We can learn from fields with more established K-12 research.

Existing strategies can help but we can always improve.

Images from Scratch & Canon Lab

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Let's continue the conversation!

@SaladwithaC

Key Contributions:

One of the few studies for this age group & in a formal learning environment.

Students with reading & math proficiencies below grade level lagged in CS performance.

Performance gaps can guide the development of strategies for struggling learners.