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TL;DR

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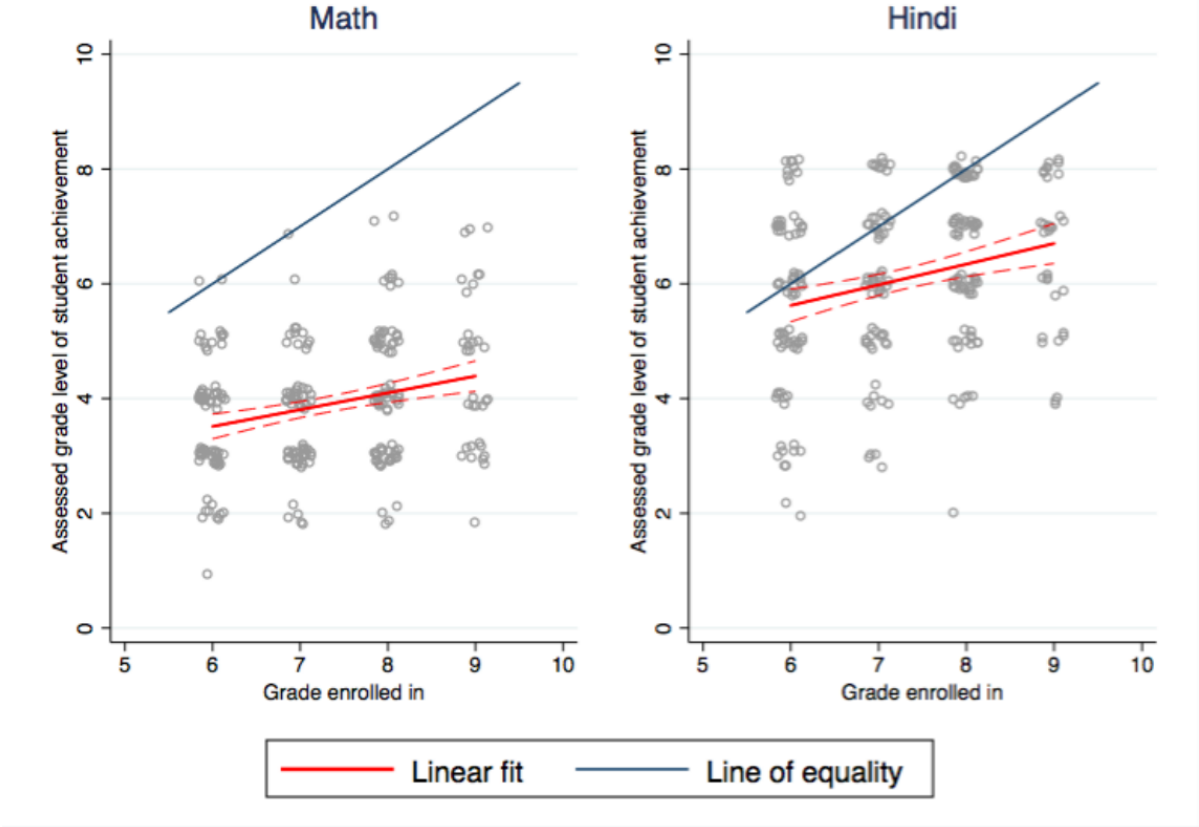
Introduction

There is ample evidence that math literacy skills have an influence on how well students do in life. "How well" is from a socioeconomic standpoint as well as academically in later school years [citation required]. Early math literacy skills comprises ability to solve basic linear equations, simple math word problems, fractions, division problems, etc.



The above image shows the results from a randomized control trial done in India[1]. On the x-axis, are the grades students are currently enrolled in. On the y-axis is their assessed grade level knowledge. The figure on the left is for math literacy skills and the figure on the right is for hindi (language) literacy skills.

In my research, I focus on improving math literacy skills. In the left graph, the red line (using regression analysis) indicates the current conditions, where for example a 8th grade student has

[1] https://econweb.ucsd.edu/~kamurali/papers/Published%20Articles/Disrupting_education_AER.pdf

the knowledge of a 4th grader. The goal is to get to the blue line which is known as the line of equality, i.e. the grade level and the assessed knowledge level match perfectly.

There are multiple ways to look at the problem, the one I am focusing on is designing math activities which interplay with executive functions (EF)[2]. Executive function is a set of cognitive skills that we use in our everyday life. We use them to learn new skills, interact with people, at our jobs, and manage daily life chores.

Similar to how math literacy skills are strong predictors for higher socioeconomic status, high executive function measures in students "may help overcome challenges of learning in under-resourced schools" (Figure 1 below).

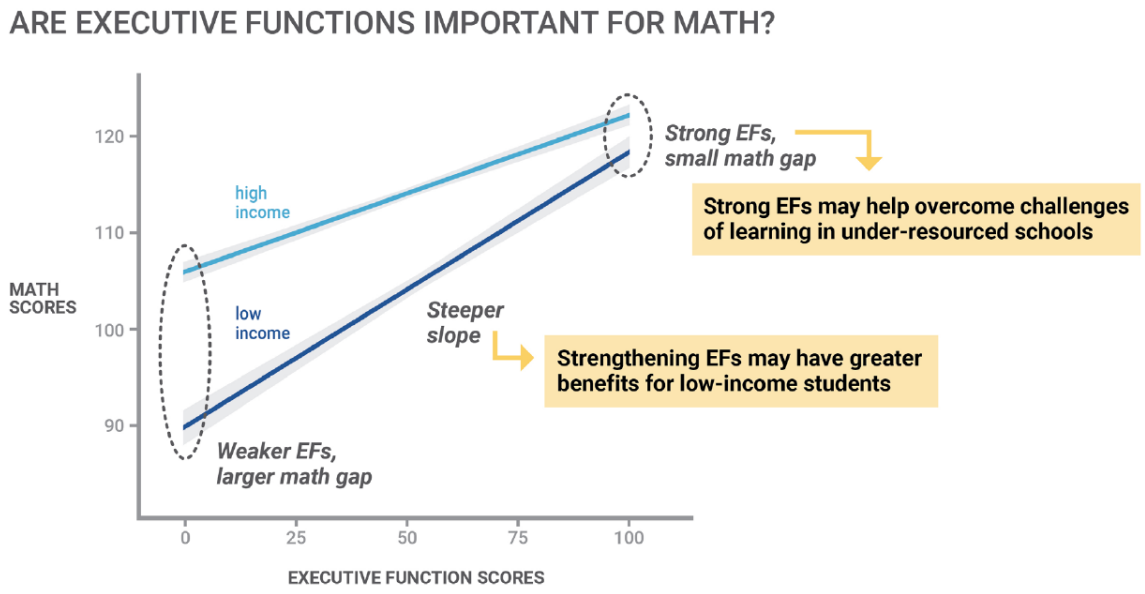


Figure 1. *The 'math gap' between children from low income households and children from high income households is reduced when children from both groups demonstrate strong EFs. This suggests that stronger EFs may serve as a buffer to challenges that may be posed to children learning in under-resourced schools (data drawn from ECLS:K, 2011).*

Figure 1. results are from a longitudinal study done in the US[3].

Three executive function measures I have been exploring are:

1. **Inhibitory Control (IC):** Imagine, there is a cake in front of you. You know it's bad for you in the long run. Can you stop yourself from eating it? In math, IC could mean stopping yourself from applying already learned rule-based patterns to trickly problems. In simpler words, avoiding silly mistakes by reading the math problem multiple times.

[2] https://www.verywellmind.com/what-are-executive-functions-20463
[3] https://nces.ed.gov/ecls/kindergarten2011.asp

2. **Cognitive Flexibility (CF):** Can you think of multiple approaches to solve the same problem? In math, what are the different ways to solve "2(x+1) = 2". Give the equation a few seconds, did you distribute terms on the left side or did you divide both sides by 2? Which one do you think is better?
3. **Working Memory (WM):** How many variables (information to solve a problem) can you hold in your memory while solving a problem. Imagine a math problem which requires you to hold "n" variables but your brain can only hold "n-1" variables.

All the 3 EFs can be measured by various neuropsychological assessments which are gold standards in the cognitive psychology field: (1) Inhibitory Control by Stroop Task, (2) Cognitive Flexibility by Wisconsin Card Sorting Task, and (3) Working Memory by N-back task.

The goal of my research has been to design math training activities which show improvements in (1) math skills and (2) proxy executive function measures.

Prototypes

I have designed and conducted experiments with real users using the following prototypes:

1. Prototype 1
2. Prototype 2
3. Prototype 3
    a. Condition A
    b. Condition B

Prototype 1 & 2

The goal of prototypes 1 & 2 was to evaluate if they can measure Cognitive Flexibility (CF) through math and if they can act as a proxy for the neuropsychological assessments. **The experiment results show these prototypes can moderately measure/diagnose cognitive flexibility.** Since both these prototypes were diagnostic in nature, i.e. they are not training people to do better math. In fact, prototype 1 doesn't even provide the student with any feedback on their answers. They are merely evaluating students' existing math skills and correlating the math activity test scores with results from a standardized cognitive flexibility test.

Prototype 3

This prototype was designed as a "linear equations + cognitive flexibility" training activity. I integrated the functionality to test multiple conditions (versions) in the prototype. If you click on the Prototype 3 link, it will either take you to Condition A or Condition B. **The preliminary results show there is mild improvement in cognitive flexibility**, I am running some additional tests to verify statistical significance.