# CyMath: Math tutoring for Engineering and STEM success

Namrata Vaswani

Director – CyMath <u>https://cymath.iastate.edu/</u>

Anderlik Professor of Electrical and Computer Engineering

**Courtesy Professor in Mathematics** 

Iowa State University

## CyMath Math tutoring + practice schedule

- Summer May 20 Aug 20
  - Saturday mornings (10-12) ISU or Zoom
  - Tuesdays (2-3pm) at the school closest to ISU
- Fall/Spring:
  - Saturday sessions: no change
  - Weekdays: 2 weekday after-school sessions
- Tutors ISU graduate or undergrad students.
- Use ALEKS.com as a base for tutoring & encourage at-home math practice
- Signup:
  - short form at <a href="https://cymath.iastate.edu/">https://cymath.iastate.edu/</a> or
  - email Prof Namrata Vaswani <u>namrata@iastate.edu</u> (ECE professor)

#### • What is CyMath

- Hybrid mode (at least) weekly math tutoring
- At-home math practice resources (ALEKS.com) and encouragement
- Start in 3rd-5th grade, follow students to middle school and later
- Tutors: STEM grad student volunteers, undergrad students (paid) & Education majors (future teachers also help motivate/manage students, run CyMath)

#### • Why?

 math learning is cumulative – without basic arithmetic skills cannot understand (scalar) algebra; all of Engineering/Computing/STEM relies on algebra and the ability to code it right

#### • CyMath Impact

- huge gains for some students; small gains for all;
- tutors find community/mentors and improve their own teaching and communication skills
- Web: <u>https://cymath.iastate.edu/</u>
- Open question: How to get and graduate better prepared Engineering/Computing students?
  - Someone needs to look at the ENTIRE K-12 to college math pipeline; Ques: How do K-5 math policies impact math needed for engineering/ML success

#### Why CyMath - brief

- An important barrier to success in Engineering course-work and jobs is the math preparation of our students. Even correct code-writing requires good middle/high school math skills.
- Since math learning is cumulative, this issue disproportionately affects students that have not been able to learn early math well
- Goal: reduce the Math learning gap while it is still small and thus eventually increase the fraction of under-served students that succeed in Engineering and other STEM majors.
- CyMath tutors are STEM graduate or undergrad students and Elementary Education undergraduate students. Grad students -- volunteers
- Currently it is running for Ames K-8 students afterschool / Zoom / ISU
  - Plans to expand to K-12 and ISU students as well

#### Details -- Why School Math critical for ML / Engineering

- Understanding machine learning / engineering requires
  - a good grasp of linear algebra (vector and matrix algebra), probability and statistics, and complex numbers,
  - and an ability to code algorithms based on these math concepts in MATLAB or Python.
  - The latter is essential to understand, develop, and evaluate novel applications of the signal processing ideas.
- However, one cannot learn linear algebra, or even learn to code it in, without a strong knowledge of (scalar) algebra that is typically taught in middle and high school.
  - Algebra also forms the foundation of the ability to understand probability concepts such as the probability mass or density function, or the ability to understand how to manipulate signals or images which are functions of time or space.
- Algebra cannot be understood without fluency in elementary school arithmetic
  - (add, subtract, multiply divide; negative numbers; fractions, decimals, and four operations with these; exponents).
- Example:
  - The ability to solve for x, y from two equations in x, y: 0.2(3x + 5) 9x + 22 = 1/2 and x y = 0.25 requires arithmetic fluency. This forms the basis of understanding the general setting of solving a linear equation in n variables, using vectors and matrices, or to code these in.

#### Details -- With AI (ChatGPT), math critical again!

- With AI (ChatGPT etc) tools providing the ability to automatically generate code snippets and code syntax, math skills are becoming even more important.
- Engineers need the ability to check the correctness of auto-generated code and understand which settings it may fail in.
- As an example, implementing least squares estimation to recover an unknown signal or vector x from measurements y= Ax + e, is a signal processing problem that occurs in a large number of engineering applications. It has a closed form solution and code for it is two lines in Python.
- BUT the code will work only if the matrix A is well-conditioned. It DOES NOT provide a warning if A is not.
- Knowing that the condition number of A governs solution accuracy is important to realize that the code may give wrong solutions when A is badly conditioned.
- Regularization techniques exist to deal with this ill-conditioning and Python toolboxes exist to call these routines. However, realizing that ill-conditioning is a problem and which tools to use to address it requires knowing linear algebra and statistical signal processing.

#### What is CyMath

- Math tutoring and mentoring program for grade and middle school students who need support
- Founded in Fall 2020. Ran for a Des Moines school till 2022 online
- In Fall 2023 year it resumed in in-person mode for ones Ames elementary school.
- It provides *school-year long weekly small-group Math support* to grade & middle school students in-need through the entire school year. Planning to expand to high school too.
- The tutors are Engineering/Math/STEM graduate student volunteers, STEM undergrads AND Elementary Education undergrads (paid)

#### CyMath Successes – March 2025

- CyMath now supports 22 students in grades 3-5 (most tutored twice a week) and about 11 students in grades 6-8.
- Of the first group of six third graders who started in Fall 2023 when Ames CyMath started,
  - One has transitioned from being at a 40-th percentile in September 2023 to being at the 85th percentile in May 2024 and at the 92nd percentile in January 2025.
  - A second student from this cohort has been showing more modest but steady gains and has gone from 20-th to 38-th to now 60-th percentile.
  - One newer student who started in Fall 2024 has also gone up from 34-th to 66-th percentile, while some of the other newer students are going up by 5-10 percentile points.

## CyMath Impact

- Impact on students (children): grades improved for all students, improved a lot for some.
  - Expect to catch outliers. Ensure the rest improve slowly
- Impact on Education majors future teachers tutoring alongside STEM grad students and faculty – see a different college math educator viewpoint
- Impact on tutors (grad students, undergrads, faculty):
  - wellbeing, find community of other math-loving students
  - teaching skills,
  - soft skills,
  - mentoring from faculty and grad students,
  - useful volunteer experience can see impact very soon

## CyMath Ongoing Plans

- Support for high schoolers and ISU Engineering students in Fall
  - Overall idea fill math gaps from past learning
  - High schoolers enroll and understand needs, run group tutoring
  - ISU: Provide curated resources and help sessions to review key high school math topics needed for an Engineering course a month before the course begins.
  - Mentoring chain formalize
    - Lunches or Zoom meetings with potential companies that will hire them
    - Seminar series on math in ML
    - Company info sessions and lunches twice a semester
    - Overall idea: everyone tutors kids; undergrads get help and support from grad students, both get mentoring from faculty

## **Open Questions**

- How to fix Math skills of our undergrads?
  - Fix math skills for high schoolers
  - Fix math of middle schoolers
  - Fix elementary (primary) math education
- Engineering & ML researchers and educators need to
  - Study or comment on the education of future teachers (math part)
    - More in-school math practice needed for fluency
      - Need not make every math lesson fun and a game etc.
    - Homework critical starting 3/4<sup>th</sup> grade individual math work needed to learn it well
    - Help kids who are behind get up to speed before middle school
    - Provide awareness for parents testing dates, purpose of testing, why early math impt.
    - Provide awareness on why early math is critical for all STEM/college success. And tools to use like Khan academy
  - And/or start math tutoring programs in their personal/professional capacity

#### Web links

- Useful links
  - <u>https://cymath.iastate.edu/math-for-all/</u>
  - <u>https://cymath.iastate.edu/how-can-i-help/</u>
  - Math for ML detailed thoughts: <a href="https://arxiv.org/abs/2409.17304">https://arxiv.org/abs/2409.17304</a>

CyMath <u>https://cymath.iastate.edu/</u> is Iowa State University's free hybrid-mode math tutoring+mentoring program that started in 2020 to support K-12 (school) students, ideally starting in grades 3-5, and following them through high school. It also directly enrolls secondary students. Its long-term goal is to increase the fraction of students from various difficult backgrounds that are academically ready to pursue and thrive in Engineering and other STEM majors in college. Most program mentors are STEM graduate student volunteers, STEM undergrads and Education undergraduates (future teachers).