Can Fixing Early Math Skills Improve Computing Workforce Success?

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Fixing early math skills of students is critical for the future of computing, machine learning (ML), and all STEM professions. We discuss ways in which STEM/computing professionals can help. We also argue why some current K-12 policies, based on short-term research, need to be critically re-examined from a long-term student success perspective.

ACM Reference Format:
Namrata Vaswani, Aditya Ramamoorthy, Mohamed Y. Selim, and Renee Serrell Gibert. 2025. Can Fixing Early Math Skills Improve Computing Workforce Success?. 1, 1 (October 2025), 4 pages. https://doi.org/10.1145/nnnnnnn.nnnnnnn

1 Introduction

This opinion piece highlights the need to fix mathematics education in elementary, and then, middle school as a critical first step for improving the math, computing and STEM skills of high school and college students. Our opinions are based on our experience as electrical and computer engineering (ECE) professors or middle school math teachers who have been directing, running, or helping run university-led free K-8/K-12 math tutoring and support programs – CyMath at Iowa State University (ISU) (www.cymath.iastate.edu) and Algebra by Seventh Grade (Ab7G) at Purdue University. Specifically, Vaswani, Ramamoorthy, and Selim are ECE Professors at Iowa State University since 2005, 2006, and 2019 respectively, with research and teaching in statistical ML and signal processing, communications/networking, and quantum information theory. Vaswani is also the Founder and Director of the CyMath K-12 Math Tutoring and Support Program at ISU. Ramamoorthy and Selim have been extensively involved in tutoring and recruiting tutors for CyMath. Gibert is the Program Coordinator for Ab7G at Purdue University and was a middle school math teacher before taking on this role. The letter [1] correctly argues that students should have access to higher-level math (needed for STEM success) if they are ready for it. This article discusses how computing professionals can help ensure that many more students are ready.

Mathematics is a foundational skill for academic and workforce success in math-intensive STEM fields such as Computing and Engineering. Math learning is cumulative. To understand this, consider ML as an example. ML algorithm design and coding requires a strong grasp of linear algebra and of probability and statistics. With AI tools providing auto-generated code, math skills are becoming even more important for verifying its correctness. One cannot learn linear algebra, or even learn to

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ACM XXXX-XXXX/2025/10-ART
https://doi.org/10.1145/nnnnnnn.nnnnnnn

code it in, without a strong knowledge of (scalar) algebra that is taught in secondary school. An understanding of basic algebra builds directly on fluency in elementary school arithmetic.

Since math learning is cumulative, gaps in math skills widen over time, leaving many students unprepared for advanced high school math courses which are, in turn, necessary for success in STEM course-work and the workforce. This fact is corroborated by research [2].

Unequal Early Math Skills. Some students face greater challenges in developing good early math skills than others, for various reasons, many of these are beyond their control. These include resource inequity – inadequate resources for free/low-cost public education, non-uniform teacher quality, family income and education levels, family math awareness levels, COVID-19 learning losses, unconscious bias, language barriers – and a culture of low expectations [3].

2 How Can a Computer Scientist or Professional Help?

2.1 School-year long and/or Summer K-12 Math tutoring and support programs

One approach to reducing the impact of resource inequity for students is to provide free out-of-school math tutoring and support. It is well-established via rigorous research studies that tutoring has huge benefits [4, 5]. But many tutoring programs end once the study ends. Our experience with CyMath and Ab7G indicates that a university professor/department led K-12 math support program can be a valuable, yet low-cost and sustainable, tutoring solution. CyMath started in Fall 2020, in online mode to help reduce the impact of COVID school closures on those most in-need. In 2023, it expanded with help from Ab7G and now supports 50-60 students in grades 3-10 weekly in hybrid mode. Ab7G ran from 2017 to 2025 for students in grades 3-7 with a goal of increasing the number of underrepresented students that are academically prepared to take algebra. Both CyMath and Ab7G also provide access to a computer based math application and workbooks, and strongly encourage regular math practice at home. Program tutors are STEM graduate student and faculty volunteers, and paid STEM and Education undergraduates. Both programs also provide occasional after-math STEM exposure activities to keep students excited and motivated about math. Interested STEM graduate students tend to be high quality volunteer tutors while some undergraduates, especially those studying to become future school teachers, are great paid tutors and program assistants. The use of an adaptive math learning app (ALEKS), along with a human tutor, makes both tutoring and at-home practice encouragement easier.

If such programs are supported by university/college and nearby schools' administration, and if they help advertise the program to help recruit tutors and K-12 students (who can benefit from free math support) respectively, the rest of the work is easy. The cost for paying the undergraduate tutors or buying math resources is minimal and can be budgeted as outreach funds in research/education grants. If funding agencies encourage math tutoring for broader impacts, it can be an easy, yet very impactful, activity. As an example, out of the 15 students that spent at least a year at CyMath in hybrid mode, all but one showed gains in math skills as measured by standardized testing done by their schools. A third of these (6) showed very large *and sustained* growth of 20-percentile points or more, e.g., 20th to 70th percentile, 46th to 85th percentile, 34th to 80th percentile, 78th to 98th percentile. Moreover, the tutoring also helped the tutors improve their teaching, communication, and presentation skills, and find community and extra mentors.

Math support programs can also be run, on a larger scale, by computing/STEM professional organizations. Math Motivators, funded and run by the Actuarial Foundation, is one such example. It would be interesting if ACM and IEEE also started similar initiatives or partnered with them. In addition, individual computer scientists and engineers could initiate such programs themselves, through the companies they work for, through local libraries or youth support organizations, or through the local schools and their parent-teacher organizations (provide in-school tutoring or after-school support). Going through an organization makes it easier to ensure all youth safety protocols are followed, e.g., background checks on tutors. We provide some how-to suggestions for the US context in https://ece.iastate.edu/~namrata/cymath_brief.pdf(slide 8).

Use of Summer Time. Summer can be used to help students who are behind catch up on missed skills. Specifically, if many more fifth graders can be made proficient in arithmetic, it would make it easier for middle school teachers to cover the pre-algebra/algebra material they need to get students ready for high school. Summer is also the time many college students and faculty are more available. Our experience suggests hybrid-mode works best.

2.2 Math Awareness Campaigns and Advocacy for Improved K-12 Math Education

Many families are not aware that early math skills are critical for future success or that math fluency requires sufficient individual practice. There is a similar lack of information on how to leverage free online resources, such as Khan Academy (that provides videos in multiple languages also) or BeeStar, or inexpensive workbooks to help students build this fluency, if school teaching does not suffice. We provide some information at https://cymath.iastate.edu/math-for-all/. Good math skills should be the least expensive to build. A related issue is that, in certain countries, e.g, in the US, K-12 math education policies (designed with good intentions) are resulting in poor math skills for very large numbers of students. We discuss these in the upcoming Section 3.

Computing professionals can help by running math awareness campaigns either themselves using social media posts, news media, or professional magazine articles; or by working with their companies' or universities' extension/outreach or public-relations wings to help run such campaigns on a larger scale. They can also advocate for better math-education policies in their local/state schools, one example is https://www.savemath.net/ and [1]. Moreover, professional groups like ACM or IEEE, that consist of members whose work depends on strong K-12 math skills, could put out position statements on these issues.

3 Discussion of US Math Education Policies and Education Research

Within the US context, significant quantitative research exists on K-12 math education. However, *the vast majority of these studies are short-term (under 2-3 years often) e.g., [6, 7]. The reasons include the difficulty of performing longitudinal studies due to decentralized school systems, student privacy laws, and students moving often.* Moreover, elementary education, secondary math education, and college STEM education are treated as different entities in research, teaching, and in policy making. Consequently, *the long term impact of policy changes such as removing homework or replacing math drills by play-based math, has not been studied.* In the absence of long-term impact studies, it may help if policymakers also consulted with STEM and high school educators.

The Policy: Little math practice and only math fun in early grades. There is a line of literature [8], that has heavily influenced US schools policies, that argues for making math fun using games in order to engage students. Making learning fun is surely beneficial, and is a great idea if there were infinite time and resources. However, in a strained public school budget system, making every lesson a game often means that there is little time left for students to do sufficient in-school math practice or for teachers to check their work. Individual practice, where a student works on math problems by themselves and not in a group setting, is essential for math fluency. Checking their work also allows teachers to see where a student is struggling and help them.

The Policy: Almost no homework in K-8. Short-term studies such as [6] conclude that homework does not help in elementary school, while others such as [7] argue that it is useful only if it is high quality. These have influenced US policies, many schools require almost no homework even in middle school. There are other studies, e.g., [9] (based on Latin American schools) or [10] (based on China's schools), that argue that reasonable amounts of homework in primary school does, in fact, improve student achievement. “Reasonable” is interpreted as 5-10 minutes per grade of school, e.g., 15 minutes in 3rd grade and 30-60 minutes in 6th grade.

A second argument against homework is that it is unfair for students who do not have parental help in the subject or who do not have a quiet space at home. We agree this is unfair. *Unfortunately, we note that this issue does not go away in high school, or college, where a lot more homework is assigned. Thus, even though the goal is to improve outcomes for all students, this actually ends up creating unequal outcomes for the students it seeks to help.*

The Policy: Not sharing information about good math resources or about standardized testing. Many families are unaware of the resources to use for early math skills building. Moreover, students and families are not informed about upcoming standardized or other tests, and are not provided feedback based on the tests. Policymakers use equity arguments to discourage schools from widely sharing this information. But more-aware parents do know all this and are often able to find out additional information. *This creates long-term success inequity for a large number of students, with various levels of disadvantage, since the test scores are used to place students into differentiated math tracks as early as sixth grade.* These tracks, that allows students to learn algebra by 8th grade, are critical for ensuring students learn enough high school math to thrive in STEM.

4 Conclusions

We emphasize the urgent need to improve early math education as a foundational step toward cultivating a better-trained and more diverse new generation of computing, ML, and STEM professionals. *Our proposed changes are essentially zero-cost and require no modifications to existing curricula, staffing, or professional development.* Instead, we advocate for establishing partnerships between school districts and nearby universities, community colleges, and computing professionals to offer hybrid-mode math support programs. Strengthening early math skills can organically support the goal of preparing more students to take Algebra 1 by 8th grade. This is recognized as a key predictor of success in advanced math courses critical for college-level STEM pathways [1]. We also urge a critical re-examination of certain education policies that may inadvertently hinder long-term student success. It is our hope that this article sparks meaningful dialogue among various stakeholders and leads to formal position statements from societies such as ACM or IEEE.

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