Modernizing Math

Envisioning Liberatory Math Futures

Optimistic Design

About this document

This document sets a foundation for envisioning new ways of navigating towards the future of math education through the desires and dreams of lived experts.

It is intended to spark the conversations and actions necessary to collectively work towards an ideal future where thriving Black, Latine, and low-income (BL-LI) students, teachers, and caregivers are equal designers and stakeholders in math education.

The document is organized in the following parts:

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+ About this project
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+ Our process
+ Targeted universalism and our focus on Black, Latine and low-income students
+ Who this document is for

Overview

"There's no such thing as neutral education. Education either functions as an instrument to bring about conformity or freedom."[1]

—*Paulo Freire*

Math is an essential component of designing a future where students, teachers and caregivers are thriving. In this future, math education will be liberatory.

Optimistic Western futurists in the early 1900s predicted exponential advances in science and technology that included flying cars and whales domesticated for mass transit.[2] While we are currently experiencing some aspects of the predicted technological advances, predictions such as the obsolescence of teachers and books have not come to be.[3] Social constructivist theories of the early 20th century established that students were to be seen as empty vessels that needed to have knowledge poured into them by educators.[4] The education system in the United States was designed to weed out students intended to conduct factory work. Black, Indigenous, Latine, and students of color (BIPOC), disabled, low-income, and multilingual students were disregarded as lacking in intelligence and given few, if any, educational opportunities. These biases shaped the predictions of the futurists as well as the stakeholders influencing the design of our current education system.

Today, we know that BIPOC, disabled, low-income, and multilingual students are intelligent and talented. We know that environmental factors and exposure to adverse childhood experiences can impact students' learning. We know that every child is different and has the ability to excel when their needs are met. While our current system is still built on the biases of the past, there is abundant opportunity to create change for the future in areas such as educator pedagogical practice, the roles of educators and students, and customization of curriculum and implementation at scale. Looking forward to a liberatory math future not only requires us to acknowledge the skills, intelligence and capacity of students—it means taking a look at how we must take action alongside students, teachers and caregivers towards experiences that allow them to thrive.

About this project

The cross-disciplinary efforts of partners and stakeholders are necessary to build and reinforce a system where students, educators and caregivers can stand resiliently in the face of an unknown future.

In 20 years, students will be living in a world that may have some resemblance to our current era but will encounter very different circumstances—environmental changes, pandemics, the impacts of globalization, changing demographics of the United States, and continued shifts in technology offer opportunities in education and will continue to impact the workforce of the future. While it is impossible to predict the exact series of events that will unfold, we can look at existing trends and indicators to help us define a variety of possible future experiences.

The following content documents insights from a companion piece by KnowledgeWorks entitled "Future Affecting Math Education: Widening the Lens of Change" about possible futures and from Optimistic Design's work in co-creating a vision for the future of math education.

How to use this document

This document and its frameworks act as a guide for stakeholders to imagine, ideate, and plan for a liberatory future of math. It can help you:

LEARN
learn about a liberatory vision of the future of math education that includes lived expert perspectives, dreams and desires

GENERATE
generate conversations that challenge the current trajectory of math education and beliefs about math futures

CREATE
create space for ideation about the levers and actions necessary to move toward liberatory math futures

Important terms & phrases

Throughout this document we utilize terms and phrases that may be unfamiliar. Below are some of the most important terms and phrases that will be used throughout this document.

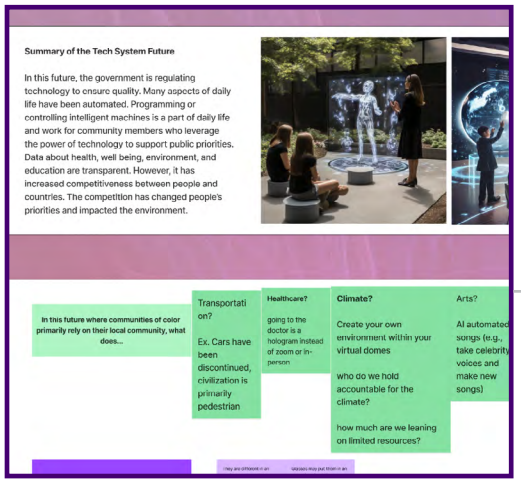
LIBERATORY EDUCATION
Positioning students to be the leaders of their own learning by helping them increase their ability to actively improve their cognition.[5]

LIVED EXPERTS
Individuals who have gained knowledge and developed expertise through their direct personal experiences, as opposed to second hand sources of information. In this work, lived experts refer to students, teachers, and caregivers.

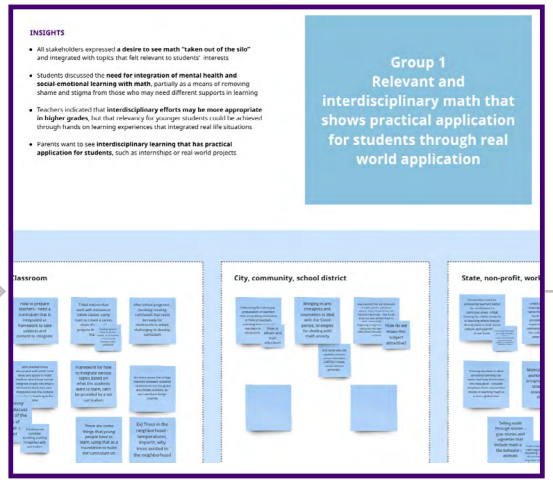
BL-LI PRIORITY STUDENTS
Students who recognize themselves as one or more of these identities—(BL-LI) Black, Latine, and low-income of any race or background.

Our process

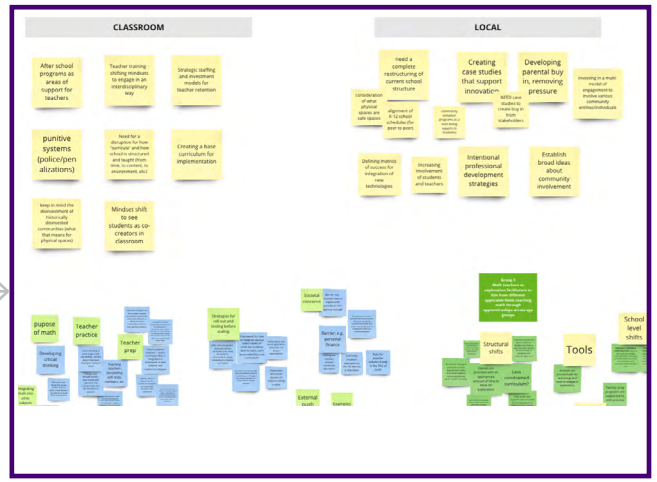
To support students, caregivers and teachers in imagining math education in unknown futures, Optimistic Design, in collaboration with KnowledgeWorks and supported by The Bill & Melinda Gates Foundation, worked extensively over eight months to engage with lived experts and subject matter experts (SMEs).



Our process began with immersive speculative co-design workshops with lived experts who ideated on the future of math in their affinity groups.



We then brought their ideas to subject matter experts, who worked on tangible actions to realize lived expert ideal futures.



Optimistic Design then worked to synthesize the insights that are reflected in this document.

We worked with:

54
lived experts

37
subject matter experts

15
states represented

12
Spanish-speaking participants

7
types of schools represented

In this work, we centered students who are Black, Latine, and come from low income backgrounds (BL-LI), as well as teachers and caregivers who come from a variety of backgrounds.

To enable lived experts to imagine how and what math should be taught in the future, it was important to immerse them in potential futures they may encounter. Using the trends identified by KnowledgeWorks through their futuring work, the research team designed immersive virtual participatory workshops that included future facing scenarios, visuals and creative activities to engage and energize lived experts about possibilities in the future. The sessions then created opportunities for lived experts in their separate affinity groups to collaborate on visions of liberated math futures. Following co-design sessions with lived experts, the Optimistic Design facilitation team worked with different subject matter experts to identify pathways to make lived experts' vision a reality. Additionally, team members conducted interviews with SMEs with specific areas of expertise, such as policy and implementation, to ensure strategic actions for executing against the requests of lived experts were documented. Throughout the process, we engaged cultural moderators who have lived proximity to student experiences and professional expertise in learning design in addition to engaging student reviewers of co-design protocols, support facilitations and synthesis. We gathered feedback from lived experts after the workshops to improve our practices.

Finally, lived and subject matter experts reviewed the final draft of the insights and provided extensive feedback. This collaborative and co-creative approach has enabled a robust and concrete vision that also includes strategies for change.

Targeted universalism and our focus on Black, Latine and low-income students

We strongly believe that all students should have access to supports, resources, and education to develop the knowledge, skills, and agency to thrive in their communities.

We also believe that race, ethnicity, gender, and socioeconomic status should not be predictors of educational attainment or economic mobility. To achieve this vision, it is important that strategies focus on students most marginalized in today's education system. "Targeted universalism" is a framework in which we set universal goals, then focus on achieving those goals through targeted strategies focused on certain populations.[7] Ideally these strategies are co-created with those who are most impacted by the changes, data and information is disaggregated so that communities can see themselves represented and hold implementers accountable. While the strategies in this framework might be focused on specific groups, they might provide more broad based (if not universal) benefits to all students. As it pertains to this work, a targeted universalist approach requires focusing on students who are least served by our current system, so all students can achieve success in math.

Research from the Department of Education's Civil Rights Data Collection shows that K-12 schools with high enrollments of Black and Latine students offered fewer math and science courses, such as calculus.[8] Additionally, schools with higher levels of enrollment of students from low-income backgrounds also showed disparity in access to higher level math courses.[9] Without access to these courses, or other supplemental opportunities for enabling mathematical thinking, students are limited in their access to college degrees and economic mobility. This data highlights the importance of centering the needs and potential future experiences of Black and Latine students, as well as students from low-income backgrounds. We focus on these students because they are often those with the least access to opportunities in mathematics and science fields and are least served by our current system.

> ***"If you're in a business and you're thinking our product doesn't seem to be working, you don't start with the people it's working for … You go to the groups that aren't using it, you go to the groups that the system is failing and you say, "What is limiting about this form of mathematics we're doing in school that's dehumanizing for people?" "What needs to be brought back?" "What are we missing?"*** [6]
>
> *—Dr. Rochelle Gutiérrez*

EXTENDING A TARGETED UNIVERSALISM STRATEGY

This work is focused on Black and Latine students and students from low-income backgrounds, but it's a good reminder that through targeted universalism, multiple strategies need to be developed for different populations in order to achieve an aspirational goal for all, and that it's not just about closing a gap between different groups. For example, strategies focused on students with disabilities, neurodivergent students, Indigenous communities, or multilingual learners have the potential of benefitting intersectional population groups, as well as contributing to all students being able to achieve the same goals.

"Too often, policymakers develop a one-size-fits-all remedy to achieve policy goals, failing to understand that different communities and populations have different needs." [7]

—Targeted Universalism: Policy and Practice

Who this document is for

We hope that this document provides policy makers, educators, and funders a direction based on the desires and dreams of students, teachers and caregivers.

Investors

- **Philanthropic organizations** looking for future-forward avenues to invest in equitable K–12 programs
- **Social ventures** committed to investing in equitable K–12 education programs
- **Private funders** of K–12 edtech platforms and programs

Educators and students

- **District and state education leaders** looking towards the future of education
- **Teachers and students** looking for opportunities to dream about the future
- **Professional learning providers** supporting educators and districts plan for the future
- **Teacher preparation programs** looking for opportunities to dream about and design the future
- **Academics and education researchers** creating the research infrastructure to scaffold the future
- **Caregivers, families, and guardians** seeking to understand ways they can support their students as we move toward an uncertain future

Policymakers

- **Policymakers** looking towards the future of student outcomes in K–12 mathematics
- **Education decision makers** interested in understanding the ideal futures that students and teachers want
- **NGOs & non-profit organizations** that want to engage in conversations about the future with the lived expert populations they serve

Technologists

- **Education technology companies and startups** looking for new ways to integrate student, teacher and caregiver co-design in the design of new and equitable educational products

Drivers and conditions that affect math futures

+ Math education today
+ Drivers of change that will affect possible math futures
+ Baseline conditions for liberatory math futures

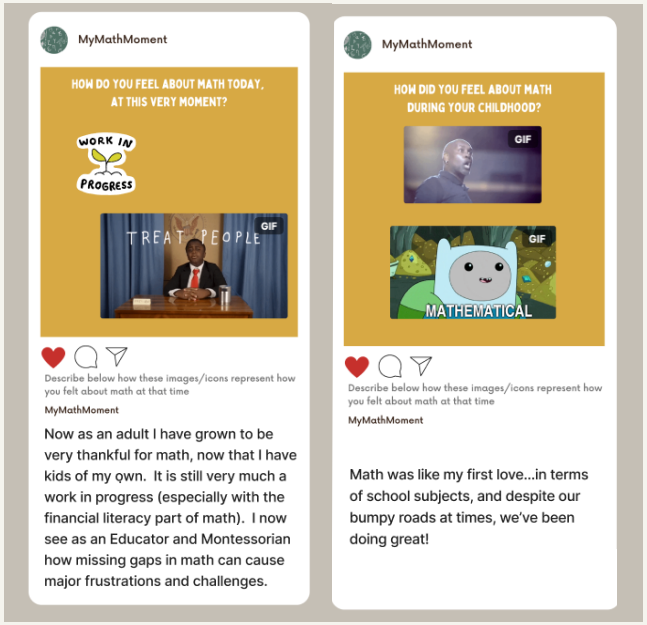
Math education today

Studying mathematics helps develop critical thinking, problem-solving, and logical reasoning skills that follow students throughout their lives and into the workforce.[11]

Math is a critical component in the infrastructure of our world, shaping not only philosophy, architecture, engineering, computer science, health, and finance, but also in areas such as data science, design, art, robotics, and governance that will continue to grow in importance in the future. As the future arrives, from advances in artificial intelligence to immutable environmental degradation, students of the future will need critical mathematical skills to help them be active designers and contributors to the future—not just consumers of it.

It is important that all students see and feel that math skills help them make sense of the world around them and solve problems in different fields so that students can be empowered to be active designers of the future. However, according to the NAEP Report Card for Mathematics in 2022, nationally, only 35% of fourth graders and 26% of eighth graders are performing at or above the NAEP Proficient level in mathematics.[12] If we disaggregate data by race—for example, in Grade 8, we see that Black students scored 23 scale-points, Native-American 18 scale-points and Hispanic 15 scale-points lower than the U.S. average. Other longitudinal studies that focus on multilingual learners show that English learners are systematically underprepared for pathways after high school.[13] While the intention is not to minimize or flatten the complex experience of students who are racialized in U.S. society, breaking down student test scores by race is a starting point to understanding where the math educational systems are failing in harnessing Black and Latine students' full potential. Students' math experiences are the result of a complex intersection of societal messaging around math, educator math identity, teaching practices, student individual identity, student math identity, school environments, and many other factors.[14] Students' experiences in the math class-

> ***"As we begin to reimagine mathematics, we have the opportunity to reimagine the mathematician."*** [10]
>
> *—Dr. Rochelle Gutiérrez*



Lived experts had the option of creating and sharing their experiences with math across their education, career and life. Image on the left is from a teacher participant. Image on the right is from a student participant.

room and society are not only defined by race but other intersecting factors such as student socioeconomic status, gender, and disability. For example, students who attended schools that served 75% or more of students impacted by poverty scored 50 scale points lower than the U.S. average in math.[15] The culture of math is also gendered, resulting in different experiences for girls and boys.[16] For example, teachers and others underestimate girls' math abilities, resulting in some teachers grading girls harder—assuming that girls need to work harder to achieve the same level as boys.[17]

In addition to identity based factors, societal and historic messaging has created and reinforced negative beliefs about math aptitude for both teachers and students. For example, students believe that struggling, making mistakes, or asking questions is seen as ineptitude, math capability is seen as static and higher level math is seen as irrelevant.[18] Educators reinforce negative beliefs, struggling to implement a growth mindset for their practices.

If the current system of math education is not working for the majority of our students, should we not work tirelessly to build something else? Something that works for all students?

THE SHAPING OF MATH EDUCATION

Mathematics education in the U.S. has changed over the decades. External influences, including the Cold War, have shaped expectations of the education system and in turn, what and how math is taught. The preceding diagram shows the influences on education.

1950s The New Math era accelerates influences on education and significant increases in STEM funding after the Soviet launch of Sputnik.

1960s The Civil Rights era & passage of Education and Secondary Education Act create Title I in support of disadvantaged students.

1980s A Nation at Risk: The Imperative for Educational Reform Report makes Americans broadly aware of perceived inadequacies of education when compared to other countries, increasing focus on accountability measures.

2000s No Child Left Behind Act established annual standardized testing in math and reading as a primary accountability measure for states and schools.

2010s State standards for learning are established through Common Core. In math, focus was placed on reducing the number of subjects learned, while increasing conceptual understanding.

2020s Covid-19 introduces an era of change in education. The first 'State of the American Student' reports are released, highlighting student pandemic learning loss.

Drivers of change that will affect possible math futures

"Understanding the mechanisms that reproduce structural inequality is an essential component of freedom dreaming." [19]

—Bettina Love

In order to situate an ideal vision of liberatory math futures, it is important to understand the context in which these futures will sit, as well as broad societal change that will need to serve as the foundation for this vision. These elements include:

Drivers of change that will affect possible math futures

These are the trends that will define what education—and society—could potentially look like in the future. An ideal future vision will need to be able to respond to, and sit within, these possible parameters.

Baseline conditions for liberatory math futures

These are the fundamental societal changes that will need to happen to provide the foundation for an ideal vision to come true.

Drivers of change that will affect possible math futures

In 20 years, students will be living in a world where environmental changes, pandemics, the impacts of globalization, changing demographics of the United States, and continued shifts in technology impact their educational and workforce opportunities. The way they utilize math to solve problems will need to adapt to the myriad environmental shifts that will arise.

Through the future casting techniques utilized by KnowledgeWorks, we gain a holistic perspective on the themes and potential changes that are expected to impact our collective futures. KnowledgeWorks identified five major drivers impacting math education, the future workforce and the lives of future learners.[20]

> ***Student:*** *"When we care about culture and collaboration in communities, we can become really successful and open up opportunities for learning, for growth, making an income, all the stuff we need to be independent."*

Inescapable Climate Crisis

Students of color and low-income students may be disproportionately impacted by the climate crises due to threats to their housing, clean water, food, and caregiver access to employment.

Diversifying education

Growing diversity amongst schools of thought and population demographics will shift the competing ideas, curriculums, and needs being addressed by schools.

Contested societies

Shifts in federal governance structures in the United States and abroad could create challenges to establish national policies that protect the rights and needs of students of color and their families.

Accelerating technologies

Accelerating technologies, such as generative AI, blockchain, augmented and virtual reality, and quantum computing, can have significant impacts on education and student knowledge expectation. These accelerating technologies can also reduce existing inequities or exacerbate them, depending on the data and information made available to these systems, as well as companies' tendencies to prioritize profits over people.

Rebalancing economics

Major changes in the workforce, some attributable to aging demographics, the possibility of technological displacement and concerns about national security, could cause economic upheaval and a reconsideration of post-capitalist economic models that prioritize human and societal well-being.

Baseline conditions for liberatory math futures

"It is only when we have plenty to eat—plenty of everything—that we begin to understand what freedom means…Then we have the time and ability to read and think and discuss things. Then we are not merely living but also becoming a creative part of life." [21]

—*Carlos Bulosan*

To shift mathematics education, we need to consider a broader lens that encompasses the nuances of math pedagogical practices and mindset shifts, as well as the overall system in which math is taught and experienced.

Students' lived experiences go beyond the classroom—they are impacted by pandemics, workforce changes, the criminal justice system, school infrastructure, and poverty. Building support for students to thrive in a liberated math future, we have to address the other experiences that have an impact on their learning as baseline conditions necessary for real change.

Meeting basic needs of students and caregivers

Students, caregivers, and educators should have access to affordable housing, healthcare, and mental health services to be able to learn, teach, collaborate, and thrive. It is also important for caregivers to have access to job opportunities in their communities that provide steady livable income.

Acknowledging the fundamental structure and history of schooling in the United States

Clear alignment between stakeholders and system leaders about the current shortcomings of the U.S. education system— with urgency, intention, and strategy to create change.

Adequate and equitable resourcing

Economic and skilled resource allocation should be restructured to ensure that adequate funding, strategic support, technical assistance, and educator talent is prioritized to historically and currently under-funded schools.

Societal alignment on the purpose of schooling

Building students' civic awareness, raising critical consciousness[21], problem solving and critical analysis skills to navigate the changing world and thrive, alongside an agreement on the role of math in supporting skills beyond numeracy.

BRIGHT SPOT

Community schools in Hartford, CT provide basic necessities like food, services, and healthcare to the surrounding school community.

Harlem Children's Zone creates supports for the students and communities that live there so students can thrive in the educational environment.

Envisioning outcomes for a liberatory math future

+ Three ideal outcomes of a liberatory math future
+ Enablers that help achieve these outcomes
+ The math that teachers and students want to see in the future

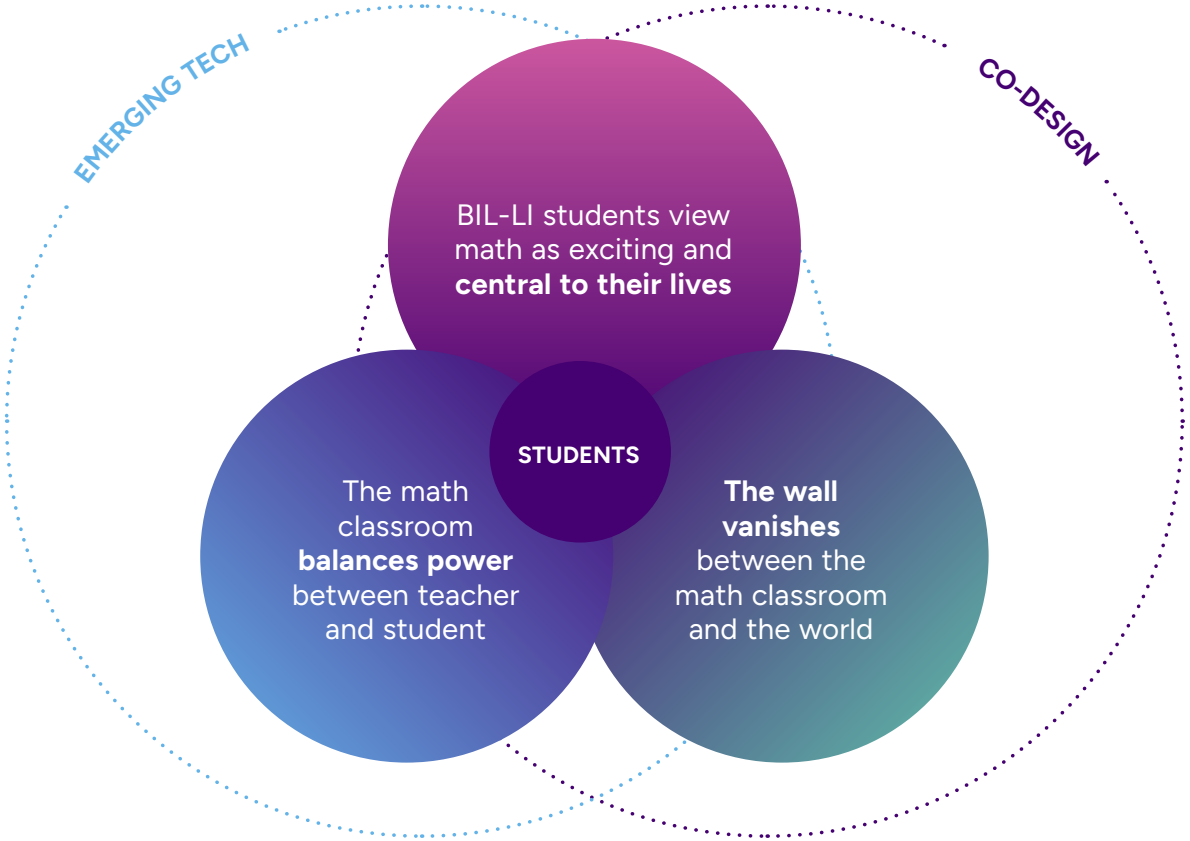
Three ideal outcomes of a liberatory math future

"The purpose of education, finally, is to create in a person the ability to look at the world for himself, to make his own decisions."[22]

—James Baldwin

Given the drivers and baseline conditions for change, there is ample opportunity to envision an ideal liberatory math future.

This future is one in which BL-LI students benefit more from transformative and revolutionary math instruction and learning environments. The idealized futures presented below were developed and informed by lived experts, who shared that a future-state definition for math will require strategic, society-wide dedication to change. Additionally, this strategic change will require an understanding of the principles for technology development, which will inevitably affect the areas of math that students and teachers will need to focus on.



1

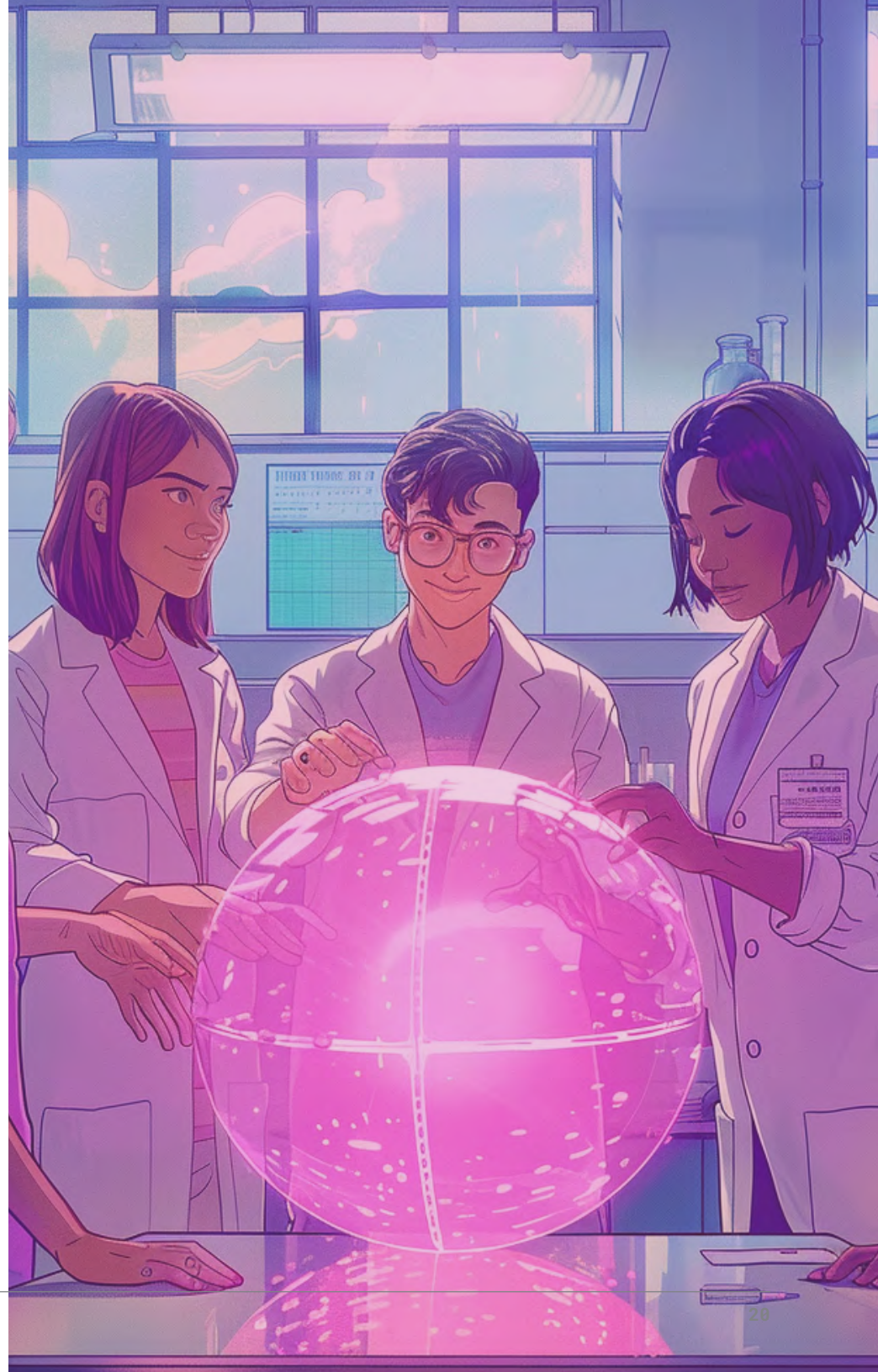
BL-LI students view math as exciting and central to their lives

Math will be a rigorous subject that is focused on critical thinking, relevant to student context, and practiced through pragmatic, interdisciplinary application.

In the future, learning math and connecting its application across a variety of other fields is perceived as a necessary, fundamental and exciting component of education by students.

Math is not only seen as related to a career, but also as an embedded aspect of their world, culture, stories, and lives. Societal narratives around math learning are positive and supportive—meaning caregivers, educators, industry professionals, and students recognize that learning math, like learning anything, requires periods of struggle and perseverance. Educators do not see student mistakes as an outcome of their race, gender or socioeconomic status. Instead, they recognize that making mistakes is part of not just learning but innovating.

As a consequence, students value their opportunities to productively struggle and see them as an inevitable part of problem solving. In the future, students, educators and caregivers don't have a monolithic mental model of math and the ideal "math person," and society as a whole is exposed to a range of identities to reinforce that math is for everyone. Students will feel a sense of belonging in their classroom. Their ability to



BL-LI students view math as exciting and central to their lives

take initiative and persist through moments of struggle will be reinforced by their teachers, peers, and other trusted adults in their lives, creating a sense of autonomy and resilience as they pursue knowledge. Their productive struggle will also support their growth mindset, providing the opportunity to build the necessary skills to smoothly transition into new areas of math and learning. As they grow into higher levels of math, they'll have access to rich, rigorous mathematics that brings in higher cognitive tasks.[23] They will see how their math knowledge builds upon itself, giving them a multi-faceted perspective on how math knowledge is applicable and relevant to their lives, hobbies, and interests. They will understand the power of math knowledge as an agent of change.

> ***Student:*** *"When I was younger, I remember math being colorful, fun, and exciting. I understood what I was learning and knew what it was going to be used for...now, I am learning knowing that the math I was learning then has purpose since I'm using it in my major and future career."*

WHAT THIS MIGHT LOOK LIKE IN THE FUTURE

A teacher reviews the digital roster of their class that includes individual and collective student strengths, growth, interests, feedback, and previous projects. The educator assistant technology contains algorithmic models that provide three different options of activities that could be appropriate for various learning styles, interests, and needs. These options are relevant to students' lived experiences and future aspirations.

The activities connect to other skills and critical knowledge the students are also developing such as social engagement with peers, self-assessment, other academic skills from other topics. The recommendations intelligently draw from the location of the class, educator input on math concepts to cover and individual student learning styles.

The teacher can accept, edit, or override recommendations, exercising their specialization and autonomy. The platform has affordances for the teacher to collaborate with their colleagues and with external experts.

Three ideal outcomes of a liberatory math future »

BL-LI students view math as exciting and central to their lives

Getting to this future requires a significant shift in the way society as a whole perceives math as a subject, what math knowledge is valued and centered, what mathematical practice looks like, and making math accessible to **all** students.

Adults in the system need to have communities of practice and other supportive environments to be able to address their own math trauma to build positive math identities.[24] Society as a whole needs to recognize and understand that making mistakes, positive struggle, and asking questions are not a reflection of an individual's capacity for engaging with math—rather, these approaches are inherent to learning. Stakeholders—the media industry, policymakers, politicians, funders, industry, and higher ed—need to intentionally work on changing societal narratives about what it means to engage in math and who can do math such that BL-LI students across K-12 see math as coherent with their identities. Additionally, peers, teachers, and other stakeholders must also see math as coherent with BL-LI student identities starting in early learning centers. Caregivers need support to engage their children to learn about their identity in mathematics to enable students to bring that into learning spaces. It also requires shifts in the ways in which math teachers engage in BL-LI students' math learning.

Deeply engaging BL-LI students can further support the advancement of the field of mathematics. For example, Dr. Rochelle Gutiérrez, professor of education at the University of Illinois, Urbana-Champaign, points out that "other disciplines

WHAT THIS MIGHT LOOK LIKE IN THE FUTURE

Students learn and apply math in real world contexts that impact them. For example, middle school students learning about ratios and rates have the ability to engage in groups and individually to apply the concepts to understanding soil water holding capacity.

They engage in a dialogue not only about what kinds of plants would work best, but to also understand the impact of the soil on the communities who are indigenous to the land, as well as those who have been forcefully or voluntarily moved there.

These conversations are often facilitated by their math teacher along with expert co-facilitators who can provide additional historical context. Students are active agents in supporting the evolution of the math content they learn to reflect their history, culture, and community.

BL-LI students view math as exciting and central to their lives

(outside of math) are seeking to radically change the discipline itself, partly through putting the needs, views and contributions of historically oppressed people first." [25] That is to say, the field of mathematics needs BL-LI students involved to evolve and grow. Students of all age groups need consistent reinforcement that the confusion or difficulty they experience in math is not a personal defect—it is a normal and inevitable part of learning. Teachers and caregivers can reinforce these budding positive math identities by emphasizing understanding and reframing student emotional responses to productive struggle.

Long-term indicators

BL-LI students apply their math skills to their education, interests, and to solve pertinent issues that are impacting their communities.

Educators, caregivers, and communities have strong math identities that support their students' own math identity development.

The field of mathematics evolves to incorporate the pluriverse of historical and global mathematical knowledge, and radically grows to incorporate history, culture, and identities of all students.

WHAT THIS MIGHT LOOK LIKE IN THE FUTURE

Teachers communicate in person with caregivers, and virtually through an AI assistant, on what students are learning, how it builds on students' existing knowledge, and how it's relevant to their lives and the future.

Caregivers receive information tailored to their own understanding and questions about the math topics, and resources and tools to support their students on their mathematical journey in the language of their choosing.

BRIGHT SPOT

The ILLest Lab at Drexel University prioritizes STEAM learning for minority students through hands-on building and culturally relevant subjects.

The Alliance of Indigenous Math Circles "create mathematical opportunities for Indigenous students and to build community among math teachers of Indigenous students while respecting Indigenous culture."

2

The math classroom balances power between teacher and student

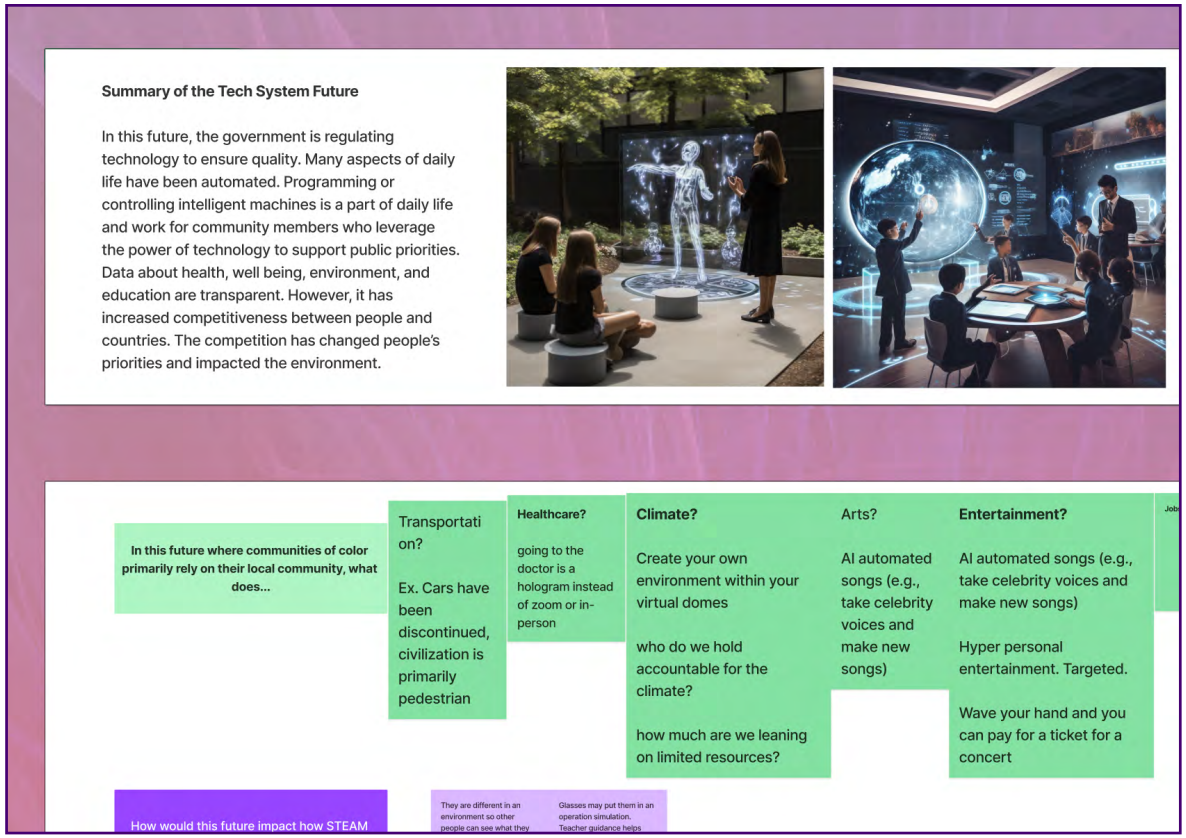
Math teaching will reorient toward a practice of student-centered knowledge-making between teachers and students. Teachers employ strengths-based mindsets to support students' positive struggle in math. Students and teachers develop healthy math identities.

In this future, students and teachers will recognize and respect one another as co-collaborators in determining the path towards mathematical learning.

Teachers will move away from "sage on the stage" to "guide on the side," and go even beyond guidance toward true co-collaboration in the design of learning experiences. Teachers will understand that they are participants in the learning process with their students, providing them with a safe space to explore and conduct sensemaking around math concepts. Teachers will learn from student perspectives to develop a shared sense of relevancy between mathematical concepts and the world students are experiencing. Students will feel encouraged to explore their curiosity about concepts they are still developing knowledge around and will perceive that inquiry as a necessary function of interrogating the world around them. Teachers will continue to adapt and shift their role based on individual student needs.

Three ideal outcomes of a liberatory math future »

The math classroom balances power between teacher and student



Using an AI-generated image of a potential future landscape, lived experts imagined how art, fashion, food, transportation, and more might exist in a different world. They then applied those same tactics to imagining how STEM education might look in that world.

Teacher: *"Having students explore mathematical concepts in a student-centered classroom is totally possible and requires the right classroom culture and support for productive struggle. Students need to understand it as a way of learning that may be a shift from ways they've previously learned."*

BRIGHT SPOT

Freire Schools are a cohort of four charter middle schools serving predominantly Black and Latine students based on the philosophy of educator and activist Paulo Freire. They center and value student voices in all aspects of their decision making with an emphasis on creativity and critical thinking.

Institute for Teachers of Color Committed to Racial & Social Justice supports educators of color with professional development to ensure that they thrive at their schools.

Three ideal outcomes of a liberatory math future »

The math classroom balances power between teacher and student

Getting to this future will mean that educators currently in practice must receive ongoing, supportive professional development opportunities from their districts that approach students, especially BL-LI students, with an affirmative, asset-based perspective that acknowledges all stakeholders' math trauma—or joy!—and incorporates strategies to build understanding together. Diversifying the educator pipeline will create more opportunities for BL-LI students to be taught by educators who have shared lived experiences. Teacher preparation programs should have math specialization for educators at the primary and middle school levels. Students should have the opportunity to choose learning topics to co-design lessons with educators while maintaining high expectations for higher order, critical thinking and problem solving. Classroom practices need to intentionally incorporate peer-to-peer learning and dialogical processing for math and away from traditional lecture and individual student practice. As a society, we need to recognize the value in equal power sharing within the classroom—to see students as knowledge-makers and not just knowledge-consumers, an idea reflected in today's Montessori approach.[2626] It is important to note that one of the underlying foundations of the transformations highlighted in this section is that educators should be well compensated and respected for their expertise to enable them to continue to thrive in the evolving role of the educator.

WHAT THIS MIGHT LOOK LIKE IN THE FUTURE

High school students identify a sustainable development opportunity in their neighborhood. For the project, the teacher knows that the students need to understand quadrilaterals, circles, and three-dimensional figures. The teacher identifies other topics, including fractals from Indigenous and African urban development, geometry in Islamic art, and Native American architecture.

Students use some project time for practice, asking questions and getting feedback on their steps. They teach each other to advance everyone's knowledge, as the class is set up to be proactive and strengths-based. This class accommodates learner variability so students who thrive working individually can learn and apply concepts. The teacher creates space for ongoing dialog for students to process learnings and to provide support during struggles. The teacher has access to professional development via their school's AI-enabled support platform to connect learning outcomes for math topics to the outcomes of the selected project.

The math classroom balances power between teacher and student

Long-term indicators

BL-LI students share beliefs about their confidence and aptitude in math, particularly in their own mastery and their ability to support the learning of their peers.

Students actively collaborate on the design and implementation of math curricula with policymakers, district and administrative leaders, researchers, and educators.

BL-LI students are taught math by educators who have shared experiences with the students such as lived experience as a Black, Indigenous or person of color (BIPOC), or having experienced low-income or poverty.[27] [28] BIPOC math educators are supported to thrive within the environment of the education system.

Students review their classroom data at the end of the year and have an open dialogue about what they're seeing and what would be needed for the following year. They are able to make data-based decisions about how they want to see in their curriculum.

Students co-design assessments with their educator and cohort of classmates to determine how to measure mastery of math concepts, change in mindset, motivation, etc. They determine which measurement tools they'd like to use or design the tools themselves.

Teachers feel valued and appreciated. They're able to grow and learn as educators through deep and meaningful interaction with students. They design their classroom and professional evaluations alongside their students and school administrators.

3

The wall vanishes between the math classroom and the world

Students will have the autonomy to explore their passions through mathematical reasoning, design their learning environments, and connect to apprenticeships and industry experts that become a core fixture in learning progression.

In this future, students will actively develop their durable skill sets in the field; and their learning, focused on applying mathematical reasoning to real world problem spaces, will be supported by apprenticeships that explore their interests.[29]

Their learning environments will be co-designed with their peers and teachers, utilizing the natural environment, collaborative in-person spaces, digital learning support, and emerging technologies. Individuals with experience applying mathematical and scientific concepts in their careers can more readily become math educators, with easily available pathways to gain education credentials.

Student: *"Since I'd like to be a choreographer, I'll need to know about financial mathematics and numeracy, but I also need to learn about AI and how I could use it as part of a performance."*

Three ideal outcomes of a liberatory math future »

The wall vanishes between the math classroom and the world

Getting to this future requires collaboration between all education stakeholders, including students, in rethinking the structural design of math learning environments beyond the traditional classroom environment. Educational leadership must create opportunities for industry professionals with knowledge of applied math concepts to work within the curriculum and in support of teachers who are facilitating the educational process. Additionally, private and public sector organizations need to create apprenticeship opportunities for students across middle and high school within their institutions for students to apply their learnings to their life and the world around them and to develop skills to support their future endeavors.

Long-term indicators

Learning happens in applied context—directly in industry, in areas of student interest.

Students design supportive learning environments with their educators, peers, and industry practitioners as support.

Student learning is not limited to the classroom. The curriculum and supportive technology makes it easy for students to learn in context individually and with their peers, through experiences such as learning labs in their school environment and beyond.

WHAT THIS MIGHT LOOK LIKE IN THE FUTURE

Students build durable skills, then leverage them in relevant industry apprenticeships that help further their exploration. Industry partners have thoughtful programs with internal champions who contribute to student learning and math knowledge making.

Caregivers offer expertise and workplaces for students to learn, collaborating with teachers and administrators to match students to opportunities. Math teachers easily connect concepts when students are in class. Students use tools such as virtual and augmented reality to simulate skill practice in areas of interest in-context.

BRIGHT SPOT

The Partnership to Advance Youth Apprenticeship expands access to high-quality apprenticeships for high school students.

Hip Hop Architecture Camp positions Hip Hop culture to introduce underrepresented youth to architecture, design, and urban planning.

Enablers that help achieve these outcomes

In order to achieve these ideal outcomes for BL-LI students, certain enablers play an important role. By harnessing these enablers, we unlock further opportunity to include lived experts in the decision making process surrounding math education. Policymakers, technologists, district and state education leaders, philanthropic organizations, and social ventures, to name a few, have the power to influence or embrace the enablers on the right side of this page.

In the section titled 'Emerging technology principles,' we provide further details and examples of the ways in which we can leverage emerging technologies and co-design to empower and engage lived experts throughout the math education system.

Teacher: *"The math of the future would have a huge emphasis on problem solving and collaborative thinking—there would be true classes designed for that. It would be more like problem-based learning, the student's job would be to spend time figuring it out."*

Student: *"I dream about a world where you don't have a job, you solve a problem in the community. You would join a group that specializes in solving a problem, and when you're done with that, you can grow and then move on to solving a new problem."*

Emerging technology can facilitate math education.

These products and systems, such as AI and other emerging tech, can work actively in the background as connective tissue — smoothing out administrative burden for educators and supporting student collaboration and personalized practice by enabling alternatives for learner variability. We discuss ways of ensuring that these technologies are supportive of BL-LI students in the "Emerging technology principles for liberatory math futures" section in this document.

Co-design is essential for designing solutions for BL-LI students.

BL-LI students tend to be furthest from access to influence on design of technology and curricula. Therefore, it is important that technology and curricula need to be co-designed to maintain student and teacher agency, choice, and voice. Changes to the math experience are co-designed with teachers and BL-LI students in a consistent feedback loop with the designers, policy makers and implementers.

The math that teachers and students want to see in the future

Through a series of co-design workshops, students and teachers generated ideas that gave us a glimpse into the math futures they imagined for themselves and future students.

While they expressed some trepidation about the future, they also looked forward to a world that was enabled by technology, giving them access to more time, more opportunity for collaboration with peers, and a greater focus on individual needs over institutional needs. As they told it, math played a role in creating these opportunities by helping students and teachers identify areas of need in local communities and how that might intersect with the curriculum students could engage with. Educators identified opportunities to push the existing curriculum based on future needs, and students wanted to have the opportunity to be exposed to a variety of pure and applied math areas to help them prepare for the future. We asked our lived experts to think about where these intersections could possibly happen and at what stage of learning might it be most appropriate for students to learn about these subjects.

There is also the meta relationship between math learning and the development of technology. Learning math is central to being empowered to become designers that create new technology. Machine learning and AI, for example, require understanding statistics and probability, linear algebra, and calculus, and the students that we spoke to recognized the relationships between their own math learning and who gets to develop new technology.

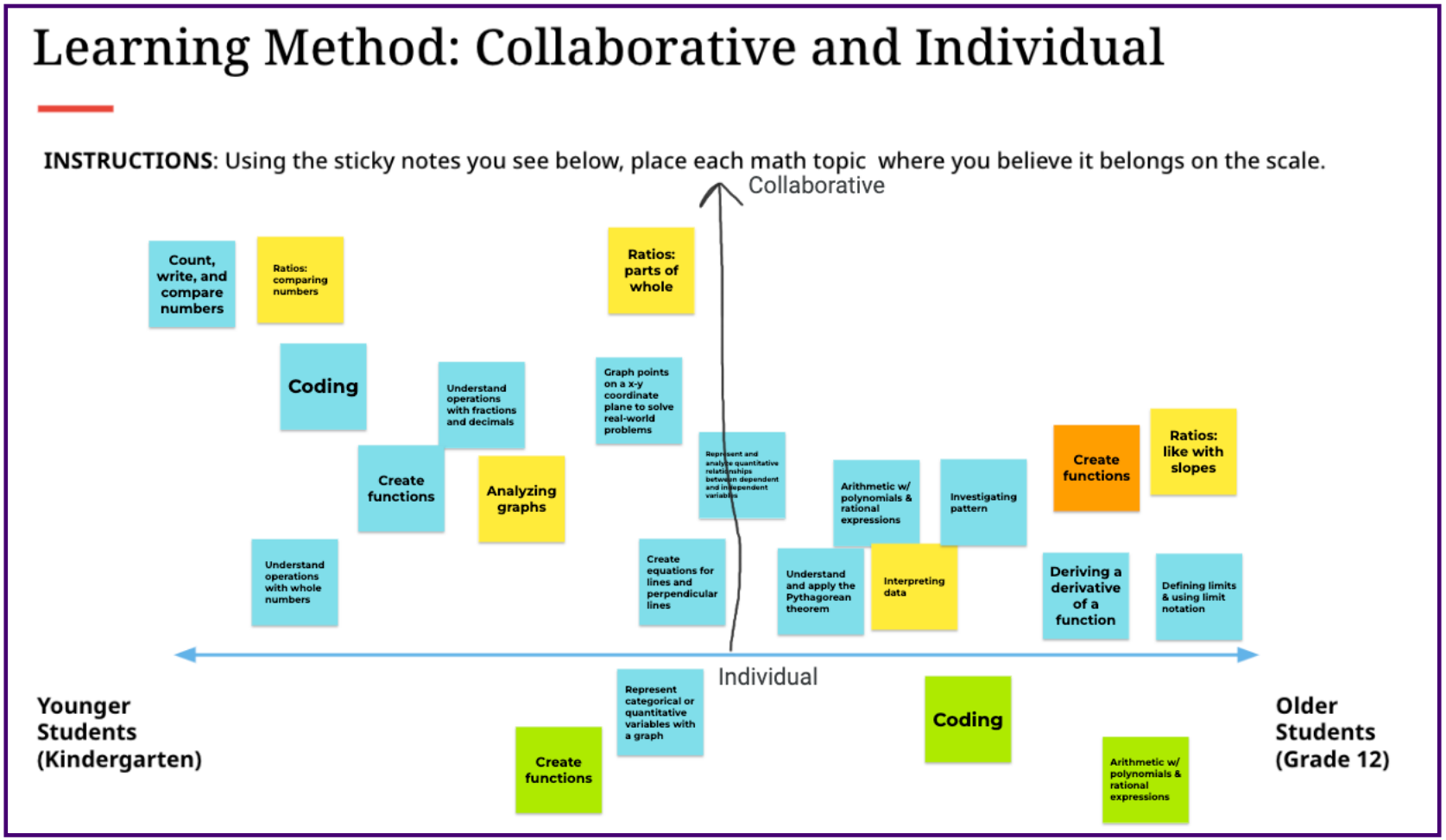
COMMON CORE STANDARDS [30]

Common Core standards shifted math learning from rote memorization to activities that support student critical thinking with an emphasis on word problems. The below table shows the current content covered in Common Core.

ELEMENTARY: KINDERGARTEN–GRADE 5
- Operations & Algebraic Thinking
- Numbers & Operations in Base 10
- Numbers & Operations for Fractions
- Measurement & Data
- Geometry
- Counting & Cardinality

MIDDLE SCHOOL: GRADES 6–8
- Ratios & Proportional Relationships
- The Number System
- Expressions & Equations
- Geometry
- Functions
- Statistics & Probability

HIGH SCHOOL: GRADES 9–12
- Algebra 1
- Geometry
- Algebra 2
- Trigonometry
- Calculus 1



In a deep dive session with teachers, there was significant discussion about the different ways students could utilize collaboration and individual time to learn math concepts.

The math that teachers and students want to see in the future

The current direction of math curriculum evolution is in line with what lived experts expect for the future.

To gather deeper insights on what lived experts believe should be taught in the future, we ran co-design sessions with math teachers and students with a special focus on how and what math should be taught. We provided reference of existing Common Core standards and grounded participants in the drivers of change, in addition to immersing them in an exhaustive visual of all the concepts in mathematics and how they relate to each other.

The following table indicates the areas of math and skills that lived experts believed could be added to the existing curriculum taught to students. The suggested content in the table below is not an exhaustive list of all the math concepts that teachers and students want to engage in, but instead highlights nuances of new concepts or ones that can be introduced earlier so that students can gain competencies in math concepts that will gain relevance in the future.

STUDENT AGE	MATH SUBJECT/AREA OF STUDY	MEASURED OUTCOMES
YOUNGER STUDENTS	**Counting + Cardinality**	• Count, write, and compare numbers
	Operations + Algebraic Thinking	• Graph points on a x-y coordinate plane to solve real-world problems
	Expressions + Equations	• Create equations for lines and perpendicular lines
	Numbers + Operations—Base 10	• Understand operations with whole numbers
	Numbers + Operations—Fractions	• Understand operations with functions and decimals
	Measurement & Data	• Analyzing graphs • Represent and analyze quantitative relationships between dependent and independent variables • Represent categorical or quantitative variables with a graph
OLDER STUDENTS	**Geometry**	• Transformations, volume, shapes, space, understand and apply the Pythagorean theorem
	Algebra	• Arithmetic w/ polynomials & rational expressions
	Ratios + Proportional Relationships	• Comparing numbers • Utilizing slopes
	Statistics + Probability	• Interpreting data • Investigating patterns
	Functions	• Create functions • Defining limits & using limit notation

The math that teachers and students want to see in the future

While there have been many successes in Common Core, lived experts still expressed a desire for students to build and utilize the critical thinking skills necessary to understand how math concepts fit together with their understanding of the world, in addition to preparing for the jobs of the future.

The table to the right shows some ideas from co-design sessions with lived and subject matter experts about how best to teach that math in an intersectional way.

BRIGHT SPOT

Citizen Math lessons teach standards-based math through real-world topics that students care about.

AREA OF MATH	SUBJECT	APPLICATION
MATH ORIGINS	**Number Systems**	• Arithmetic with polynomials—matching activity or scavenger hunt, algebra tiles
FOUNDATIONAL MATH	**Set Theory**	• Using unions and intersections to consider wellbeing or what provides us wholeness and wellness
	Geometry	• Creating exploratory proofs or deriving the formula together in Pythagorean theorem • Applying Indigenous mathematics and cultural practices • Fractal geometry for innovative urban planning
	Algebra	• Creating Functions, measuring total physical response, collecting data, or simulations (ex. responses to radioactive decay)
PURE MATHEMATICS	**Complex Analysis**	• Solve structural engineering problems like calculating the potential acoustic impact of factories in small towns Interpreting data
	Graph Theory	• Using nodes and edges determine the shortest distance or quickest path for food delivery and other courier services like Uber or Amazon drivers
APPLIED MATHEMATICS	**Global Math**	• Ethnomathematics; studying the relationship between mathematics and cultures • Applying Indigenous mathematics and cultural practices
	Game Theory	• Find theoretical pros and cons to issues facing society. Discuss whether solutions are practical and applicable.
	Computer Science	• Understanding cryptology and application in global security
	Architecture	• Creating story problems with ratios of slopes and how they might relate to building angles

Establishing a liberatory mindset

+ Challenging current assumptions
+ Adopting new mindsets
+ Theory of change

Challenging current assumptions

"When you plant lettuce, if it does not grow well, you don't blame the lettuce. You look for reasons it is not doing well. It may need fertilizer, or more water, or less sun. You never blame the lettuce." [33]

—Thich Nhat Hanh

Chicago Public Schools defines liberatory thinking as "...the re-imagining of one's assumptions and beliefs about others and their capabilities by interrupting internal beliefs that undermine productive relationships and actions."[31]

To engage in transformational change, we collectively need to adopt a liberatory mindset. This means adopting mindsets that challenge current assumptions and that shift the white-dominant perception of BL-LI students.

The following statements challenge common assumptions about BL-LI students. These statements focus on the systemic barriers and cultural attitudes that contribute to inequities that prevent students from being their best in today's educational system.

ASSUMPTION

The current US education system is equitable. When students do not succeed, it's because of their own deficiencies.

REALITY

The education system has been exclusionary to BL-LI students. The system was intentionally designed to be exclusionary, inequitable, and elitist. [32]

ASSUMPTION

The physical school environment has always been open, free, and accessible to all students.

REALITY

BL-LI students have experienced oppression in school environments for decades.[34]

ASSUMPTION

BL-LI students might not have the aptitude for mathematical thinking.

REALITY

All students have the aptitude and ability to learn rigorous and relevant math.

ASSUMPTION

All school districts currently have the same access to resources (such as high quality educators, funding, in-kind resources) and have throughout history.

REALITY

Public schools that are primarily BL-LI student-serving are and have been systematically under-resourced.

ASSUMPTION

Students are not unique in their needs, learning variability, and communication.

REALITY

The average student is a myth. There is no "average" student that all other students can be measured against.[35]

Adopting new mindsets

The following perspectives help establish the mindsets for making transformational change for BL-LI students.

Asset-based

Educators recognize, uplift, and champion the talents and gifts of priority students. Recognize that they have the aptitude for mathematical thinking.

Student-centered

Educators and caregivers work to eliminate "adultism" in decision making and system design and center student voice, agency, and desires.[36]

Equity-centered

Systems that are designed should prioritize an approach that considers and meets the needs of students who are currently underserved to be able to meet the needs of all students.

Systems thinking

This encapsulates a mindset that decision-makers need to embody: evaluating the incentives for various stakeholders in the system, and ensuring that the incentives actually serve students. The approach to the system should be student-centered.

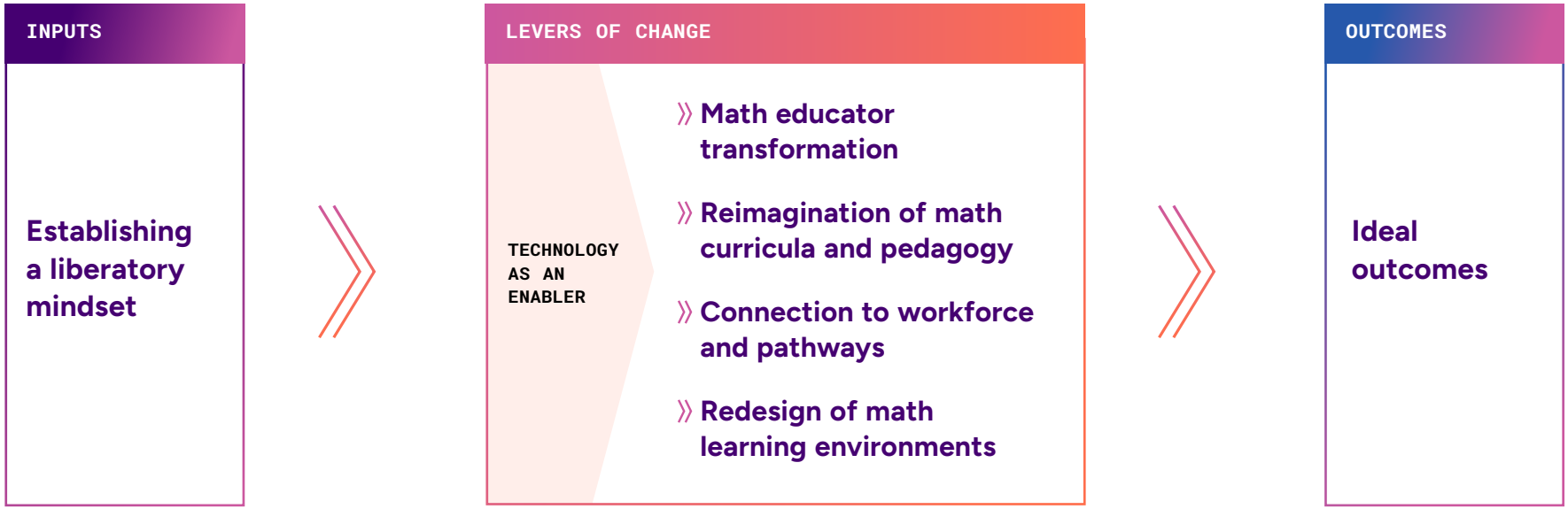
BRIGHT SPOT

The Institute for Liberatory Innovation has created the Equity Scholar in Residence program, which provides support and professional development for teachers interested in developing their learner-centered pedagogy.

Theory of change

A theory of change acknowledges that there are certain inputs—usually in the form of resources—that precede actions that can be taken to create change.

We've touched on the ideal outcomes of a liberatory math future. In order to achieve those outcomes, strategic action can be taken by using the levers of change. In this case, the inputs that affect change are not only the baseline conditions that we discussed previously but also a societal shift into a liberatory mindset.



Emerging technology principles for a liberatory math future

+ Emerging technology principles for a liberatory math future
+ Expectations about AI and potential use cases
+ Principles that prioritize equity
+ Five principles for developing and using emerging technologies

Emerging technology principles for a liberatory math future

Technology is the enabler that acts as a throughline for the other levers we'll discuss further on. In order to define the role of technology we have technology principles that would drive its development and use. Designing technology that seeks to achieve specific outcomes requires North Stars for development and use. Principles serve as guidance for designers, developers, and technologists looking to create edtech products that will be used by the students, educators and caregivers of the future.

The principles we outline in this section are specific to technology and the co-design methods that should be utilized to create it in a liberatory education environment, especially for BL-LI students.

"Technology is only as powerful as the communities that guide its use." [37]

—Justin Reich

"We should not only think about how technology can assist teachers and learners in improving what they're doing now, but what it means for ensuring that new ways of teaching and learning flourish alongside the applications of AI." [38]

—Vicki Phillips, CEO of the National Center on Education and the Economy

WHAT DO WE MEAN WHEN WE SAY TECHNOLOGY?

Though we are often referring to Artificial Intelligence (AI), we are also thinking about the variety of front-end user experiences that constitute digital technology.

When considering technologies of the future, AI will play an instrumental role within digital systems, acting as a foundation for most, if not all, front-end digital experiences. Some of the technologies we are considering for use in math education include:

- Computer vision, generative AI and other forms of algorithmic applications used for personalized learning, instructional assistance and design, teacher training, grading, and assessments
- Augmented and virtual reality experiences
- Online and virtual learning platform or software
- 3D printing and other tools for physical making
- Communication devices and the Internet of Things
- Robotics

Expectations about AI and potential use cases

With the recent maturation of generative AI based on large language models (LLMs) such as ChatGPT, society has developed a collective expectation that AI will be integral to our lives and learning, potentially having both positive and negative consequences.

Not only will students need to be equipped to understand and navigate AI as a technology that will affect their experiences in the workforce, but they should be empowered to design and develop AI in a way that does not cause harm.

When we talk about potential harm of AI, we should not be distracted by either the hype of a utopian vision of AI embraced by today's tech industry leaders nor the fear of a dystopian vision of a sentient general AI that will destroy humanity that other tech leaders espouse. Rather, we should focus on how they are reinforcing or creating inequities that already exist. According to MIT professors Daron Acemoglu and Simon Johnson, "The consequences of any technology depend on who gets to make pivotal decisions about how the technology develops."[39] Algorithmic bias can cause harm to groups at the margins, such as those in Black and Latine communities.[40] As data scientist Kishawna Peck has said, "We [Black people] are more susceptible to being harmed by [AI] products. We're more likely to experience algorithmic harm."[41]

With that said, both opportunities and risks arise when considering the use cases for AI in education, particularly for BL-LI students. The primary risk concerns revolve around potential discriminatory bias based on historical data and input within AI models, as well as potential violations of student privacy. The following use cases in learning, teaching, and formative assessments articulate not only great opportunities but also how these risks may show up in varied ways as AI becomes more ubiquitous in classroom experiences.

> ***"AI brings educational technology to an inflection point. We can either increase disparities or shrink them, depending on what we do now."***[43]
>
> *—Dr. Russell Shilling*

Learning opportunities

Learning opportunities	Risks
AI used for social learning, not just cognitive skills. Applications of AI are currently focused not only on cognitive skills but even more narrowly on rote or procedural learning, such as basic operations in math.[42] As AI becomes more sophisticated, not only will it enhance conceptual and creative learning, but it can also integrate social and emotional learning (SEL) and other social aspects of learning. **Example:** Recognizing communication patterns between students when working in groups to help students navigate conflict, as well as prompt students to engage in creative collaboration. AI could also prompt students individually to reflect on how they might be empathetic to their fellow students.	• AI models may have trouble navigating the diversity of student reactions, responses, and emotions, particularly for students who are, for example, neurodiverse or who may present unique patterns of communicating.
AI can be used as a bot that supports student metacognition, including reflection on learning, self advocacy, and efficacy. **Example:**Analyzing language and answer patterns to identify when a student is struggling with a problem to provide students with proactive scaffolded reflection. This can bolster metacognition by helping students self-identify new approaches to try, setting new goals and interrupting negative thought patterns.	• Lots of listening and data collection could be required, and it might require lots of training and customization for AI models to accurately recognize patterns.
Personalizing and adapting content and delivery to better serve students with diverse needs. **Example:** For a student with a hearing impairment, AI could help them while making a presentation in sign language and interpreting it into voice for the other students. Or, for neurodiverse students, alternate learning paths can be used to reflect their learning strengths.	• For example, the ways that data is collected via always-on listening and recording, could violate students' privacy. • Designers would need to ensure that all personalized learning paths offered by AI are connected to academic success and are not inadequate. • AI models might not be designed with intention from a disabilities perspective, so this will need to be ensured that they serve all students.

Teaching opportunities

Teaching opportunities	Risks
AI can take over the administrative burden to shift teachers' focus to the more valuable space of interaction with students. **Example:** AI could support teacher lesson planning, providing teachers with options for the day's lesson based upon previous lessons and techniques in which students achieve mastery and that students enjoyed. Current examples are Diffit and Schemely, which are generative AI-driven platforms that help teachers create lessons and activities.	• Content generated might become directive and hence remove educator choice and agency in designing lessons that truly resonate with their students. Over reliance on this type of technology can reduce opportunities for teachers to exercise their individual creativity and expertise.
Data collection and insights generation that may improve teacher professional development. **Example:** AI cameras and listening devices could gauge the amount of dialogue and discussion in a classroom and suggest ways that a teacher could improve.	• The collection of data could result in unwanted forms of surveillance that could be used in unintended ways to profile or harm students or caregivers based on their identities or preferences.
AI could learn from contextual inputs from teachers and students to make teaching and learning more culturally relevant and responsive. **Example:** AI can help make suggestions for instructional design based on what has previously resonated with students in the teacher's class, as well as suggestions for connecting instruction to community, local, or global news to add elements of criticality.	• Incorrect assumptions, and even stereotyping, can result from AI trying to recognize patterns that may need human nuance to unpack.

Potential use cases »

Formative assessments opportunities

Formative assessments opportunities	Risks
Enhancing feedback loops—making them timely and relevant —for students to improve help-seeking and help-giving. Students can engage in a growth mindset by being able to ask for help. **Example:** An AI assistant can detect a student who is "wheel spinning" and help a student identify where they might need help. [43]	• The patterns in the data could be used by others to penalize students if they end up being used for evaluation other than formative growth.
AI could be used to provide continuous assessment, to alleviate the burdens of traditional forms of testing knowledge such as quizzes and tests. It could reduce burdens on both teachers (administering tests) and students (preparing for tests and the stresses that accompany test-taking). **Example:** AI can observe student problem-solving, giving teachers a sense of students' individual and collective progression. It can also allow students to monitor their own progress and make adjustments.	• Students may recognize differences in problem solving methods and adjustments given to other students, which could reinforce insecurities about their capabilities.

Principles that prioritize equity

To consider how new technology is created, we have articulated five principles to adhere to in its development.

While ideas like co-design, active learning, and data autonomy may not seem like new concepts, it's worth acknowledging the gaps between these discussions and what happens in reality when educational technology is developed and used.

Even when new technology is intended to be "disruptive," it is often designed and developed in ways that reinforce the status quo that continually marginalizes some students and privileges others. As Justin Reich reinforces in *Failure To Disrupt: How Technology Alone Can't Transform Education*, technology experiences, such as massive open online courses, often are portrayed as a silver bullet and that people believe the myth that to create equitable experiences, we need to just address issues of digital access. However, he points out that the most intractable issues when it comes to equity are the social and cultural obstacles: "Matt Rafalow's three-school case study…reveals how even when technology is held constant across different schools, teachers can celebrate technology usage by privileged students while questioning it among other students." To paraphrase sci-fi writer William Gibson: the future is already here. It's just not evenly distributed.

To consider the role of technology, and how to best design it to be future proof and equity-centered, we've created a set of principles that could be used as prompts when imagining, funding, or developing new technology for BL-LI students and their learning environments. The principles can not only help create direction for the development of emerging technology, particularly AI, but also drive the reduction of harm caused by those technologies.

Technology development resides in a complex system of access to knowledge, job opportunities, and capital. With this context in mind, it is also important to ensure that people with shared lived identities with BL-LI students have access to the knowledge, job opportunities and financial capital to design, develop, and scale education technologies that can support the proliferation of equity first math learning.

If we start developing technology now according to the following principles, we establish the foundation for future technology development and use it to put equity first and truly push the boundaries of math learning.

Five principles for developing and using emerging technologies

Principles for development
of technology products and systems

1 Co-design and transparency

Technology needs to be created and developed in community with those most marginalized within the system.

Principles for use
of technology products and systems

2 Creativity

Technology should diversify ideas and promote creative thinking.

3 Active learning

Technology should prioritize inquiry-based learning and productive struggle.

4 Human relationships

Technology should enhance and prioritize human relationships.

5 Data autonomy

Data collection practices should prioritize the autonomy and consent of students.

1

Co-design and transparency

Technology needs to be created and developed in community with those most marginalized within the system.

PROMPTS

The following prompts are intended to encourage reflection and dialogue throughout the design and development process of emerging edtech.

- Are there BL-LI technologists who are decision makers when it comes to funding, research, and development?
- Are there members of the development team who are from BL-LI communities?
- Is it being reviewed, co-designed, and tested with BL-LI students, parents, and educators?
- Are BL-LI students, parents, and educators given the opportunity to provide feedback and see their feedback reflected in the changes to the product, platform, or system?
- Are BL-LI students, parents, and educators given the opportunity to design new technology?

Not only do humans need to be "in the loop and in control," but a targeted universalist approach is required to co-design equitably. This means leading with "those who are farthest away from opportunity," and BL-LI students serve as a good example of a group prioritized by this approach.[44] Researcher Ruha Benjamin has stated that process matters as much as endpoints, that we need to consider how a tool is created and who is involved.[45] This is especially important in edtech as students—whose outcomes define success in the system—have the least amount of power.

BRIGHT SPOT

The Distributed AI Research Institute (DAIR) is conducting community-rooted, global, and U.S.-based research on AI technologies. They take an equity-first approach to conducting research and using data to equip historically marginalized groups with the tools needed for change.

In addition, throughout the development of emerging technology, and particularly in the development of AI, there needs to be transparency in terms of the inputs (training data) as well as the results of what is being targeted. This should involve feedback loops, such as this example from the U.S. Department of Education: "[To] design AI-generated homework support for students, teachers' in-depth understanding of the cognitive, motivational, and social supports their students need will provide much-needed guidance as a homework-support chatbot is designed."[43]

True co-design also presents the opportunity for students and educators to learn about emerging technology—and be equipped to not only think critically about it, but also to be the empowered designers of those very technologies in the future. For example, if teachers understand how AI models work, they can design AI models that best respond to their—and their students'—needs.

2

Creativity

Technology should diversify ideas and promote creative thinking.

Algorithms often flatten creativity in favor of efficiency and tend to reinforce existing patterns of thinking and culture. Consider how platforms like YouTube and Spotify recommend media that tend to be reinforced by your previous consumption.[46] In another example, research has shown that the use of turn-by-turn directions such as Google Maps reduces spatial learning.[47] In education, this approach trains students to do things the way it's always been done, rather than seeking out new—and potentially less efficient—ways of thinking and problem-solving. AI developers must actively consider how their software can support creative and diverse thinking.

PROMPTS

The following prompts are intended to assess and engage with the potential flattening effects of emerging technologies that have made it out into the market.

- What are the trade-offs that users have to make in the name of efficiency?
- Are there ways that AI can prompt students and teachers to explore new ways of doing things rather than being directed by existing patterns?
- Does the experience homogenize the way students might think and problem solve?

3

Active learning

Technology should prioritize inquiry-based learning and productive struggle.

BRIGHT SPOT

Flip digital tool helps students use video to share their thinking, process and feedback.

Today's students and teachers—as well as those in the workforce—often use AI to give them answers on their work. For example, 39% of U.S. teens in one survey said that ChatGPT is acceptable to use to solve math problems.[48] We know that students learn better through active learning, so technology can be designed to intentionally support that rather than the passive consumption of information.

PROMPTS

The following prompts should be used when trying to understand the learning efficacy of the emerging technology in the market when being used by students.

- Is the use-case primarily 'giving the user the answer'?
- Are users focused on inquiry rather than lecture?

4

Human relationships

Technology should enhance and prioritize human relationships.

PROMPTS

The following prompts should be used when testing emerging technologies to generate conversation about the role technology plays in creating and maintaining human relationships.

- Does it replace what might otherwise be a valued human connection or interaction?
- Are there ways of enhancing relationships between students and teachers?
- Does it take a support role rather than a replacement role?

AI-powered instructional and teaching assistants have the potential to lift administrative burden for educators, as well as help to further explain math concepts to students. For example, rather than replacing human tutors, AI can be used to facilitate the quality of tutoring, particularly for under-served students.[49] These connections are crucial not just to understand concepts but also to connect BL-LI students to mentors (such as human tutors) that can increase their access and network.

BRIGHT SPOT

Raising Good Gamers brings together students, social innovators, and game creators to inspire youth to explore civic issues and STEAM through games that engage their creativity and social and emotional learning skills.

Students we've spoken to also made it clear that they thought AI would affect every facet of their lives—worrying that, in some ways, it might replace people—particularly in the workforce. A philosophy that might be adopted as we consider the role of AI would be to think of it as augmenting human capabilities, rather than automating everything. A good metaphor is to think of it like an electric bike rather than a robot vacuum cleaner: with a vacuum cleaner, the human is out of the picture and the vacuum does its work on its own. With a bike, a human is in control and they can do what they want to do better.[43]

Student: *"When we talk about AI, I get nervous about the uselessness of humans...it feels like there's no reason to learn anything because the tech is going to take over all of the jobs in the future."*

Caregiver: *"I'd like to see a world where we have harmony with tech... where we use tech in a way where students are able to feel less sense of competition and are more able to build community."*

5

Data autonomy

Data collection practices should prioritize the autonomy and consent of students.

Powerful AI platforms are dependent on wide-ranging data collection to inform and train their models. However, unfettered data collection can be harmful, particularly if it is used in ways that are unintended. Students in marginalized groups often suffer most from the historical biases embedded in algorithmic systems.[50] Developers of AI systems need to build in transparency for end users, as well as the potential to opt out of systems that users feel may cause them harm.

PROMPTS

The following prompts should be used when determining data collection, reporting, and accessibility early in the design and development process.

- Are students able to give knowledgeable consent to the user of their data?
- Are there ways of opting out of data collection?
- Is there transparency on how collected personal data will be used?
- Are there ways for designers and developers to use disaggregated data to better understand the impact on those who are marginalized?

BRIGHT SPOT

The Algorithmic Justice League is leading the movement to equitable and accountable AI. They raise public awareness and build the voices of those who are most impacted by the technologies.

Levers of Change– Strategies, Indicators and Actions

+ Levers of change
+ Math educator transformation
+ Connection to workforce and pathways
+ Reimagination of Math Curricula and Pedagogy
+ Redesign of math learning environments

Levers of change

Now that we've covered the principles for developing technology that can act as an enabler for change, we can focus on the levers which can be activated to move us towards the ideal outcomes imagined by lived experts.

To sustain transformational changes suggested in the ideal outcomes, it is necessary for the changes to occur on top of a solid systemic and societal foundation. To get to this solid foundation, it is important to meet and exceed the baseline conditions for a liberatory math future, summarized on 17 of this document. Designing and implementing changes to multiple systems impacting students, caregiver, and educator experiences takes time, funding, intentionality, strategy, and accountability. While these changes can feel daunting, it is critical to commit to and implement them in parallel to the work within the education system. Once education decision-makers have shifted toward a liberatory mindset, it is important for them to utilize the levers to inform the actions that they can subsequently take to make transformational change that will lead to the ideal outcomes.

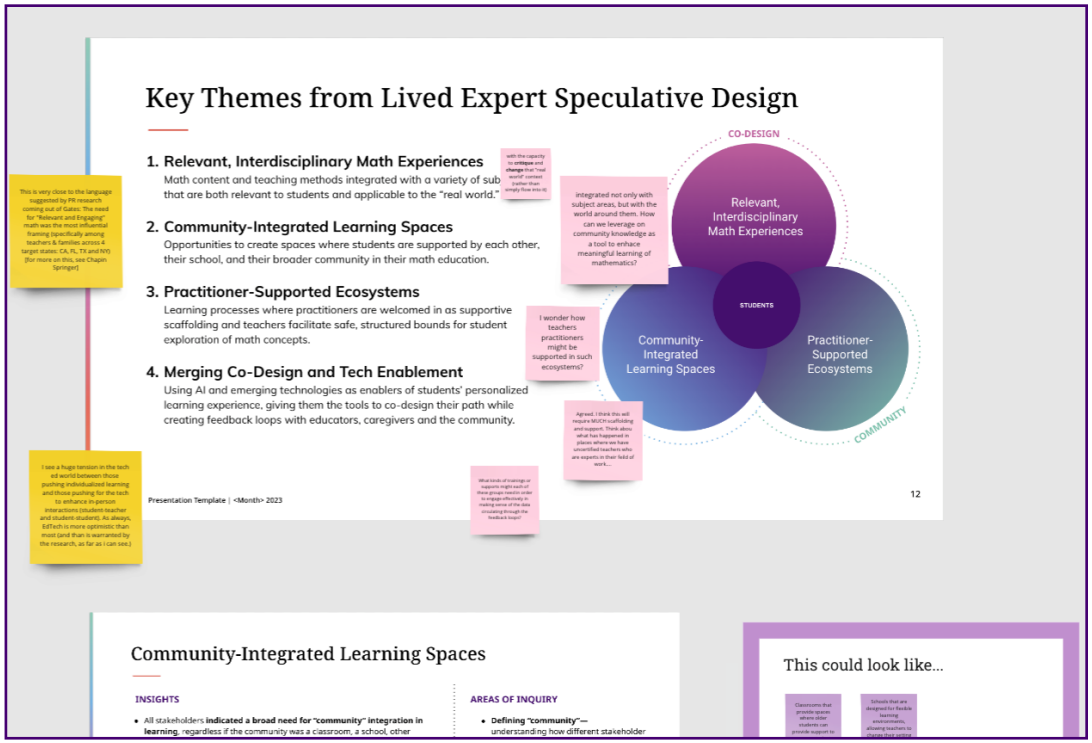


Image shows content generated in the opportunity ideation workshop with subject matter experts where they identified tangible actions and next steps to realize the ideal future of math education that lived experts imagined.

The four levers that can be used to enact change are:

Math educator transformation

Transforming math teacher education, supporting, training, and providing resources for teachers and other support educators as they engage with students and the education system at large.

Connection to workforce and pathways

Developing relevant experience opportunities that utilize mathematical reasoning that students can use to create or find opportunities to thrive in the future they will experience.

Reimagination of math curricula and pedagogy

Developing math curriculum that grows students' critical consciousness through supported and evolved teacher pedagogical practices that are focused on learning together.

Redesign of math learning environments

Designing flexible learning environments that give students and teachers more opportunities to integrate math as an explorative practice.

Transforming math teacher education, supporting, training, and providing resources for teachers and other support educators as they engage with students and the education system at large.

How might we transform and diversify the roles of math educators and support staff through teacher education, support and training in order to shift their engagement with students and navigate the education system at large?

> ***Teacher:*** *"We could have a world where advanced tech supports teacher and student better through more responsiveness, reducing the onerous burden of labor on teachers so we can be more productive in our impact."*

Indicators

New Culturally Responsive Math Teaching standard includes culturally relevant and sustaining teaching practices, incorporation of non-dominant math practices, student-centered knowledge making, interdisciplinary teaching, asset-based discussions, and builds on students' funds of knowledge.[51] *Requirements also focus on historical context of math, experiences of priority students, approaches such as applied and problem-oriented learning, peer-to-peer learning, and power-shifting.*

Actions to get there

- Co-design with Black, Indigenous, Latine, multilingual, disabled, and low-income students, educators with similar identities, and subject matter experts with lived experiences.
- Fund, design, and implement non-punitive and accessible professional development to meet standards for in-service teachers.
  - Technology support to coach educators as they transition to meet the standards.
- Develop financial and in-kind incentives for educators and districts to align with standards
- Create incentives for pre-service teacher programs to align pilot and scale math specialized educator training, especially for elementary and middle school teacher candidates.
- Create partnerships between hiring districts and teacher preparation programs to ensure pre-service educators graduate with skills that align with the standards.

BRIGHT SPOT

The STEP UP and Teach Program by the Los Angeles Unified School District offers paraeducators professional development support and financial assistance for those seeking the credentialing to become teachers in STEM subjects, Special Education, or Multicultural and Multilingual Education.

Indicators	Actions to get there
Healthy influx of math educators [5253]	• Design pre-service and in service professional learning focused on building more security and positive identity for educators teaching math. • Develop policy to increase the number of teachers through alternative certification programs and pathways. • Develop policy across states to enable pathways for community subject matter experts and high school students to gain math educator credentials of professional or paraeducator. • Create equitable and sustainable funding for strategic staffing supported by equity focused leadership at the federal level. • Develop flexible state and district policies to support strategic staffing at the school level. • High-quality federal technical assistance (TA) is made available to help districts staff based on internal needs and learn more about leveraging professional educators in addition to community and paraeducators. • Support and recruit from BL-LI programs focused on increasing BL-LI professional and paraeducator pipeline. • Provide technical assistance to districts to support and retain BL-LI professional and paraeducators.
District level innovation in educator infrastructure	• Provide funding and technical assistance to principals to create innovation "labs" within their schools, where in-service educators can develop and practice new skills and get feedback. • Set up district communities of practice to education leadership to learn from one another and implement innovative approaches to team structures and curriculum implementation.

BRIGHT SPOT

The Ethnomathematics Graduate Certification and Master's Degree program at the University of Hawaii enables mathematics educators to engage their students in solving rigorous, relevant and contextualized mathematics tasks.

The Center for Black Educator Development Teaching Academy has a fellowship pipeline that supports aspiring teachers with coaching, training, and Black pedagogical frameworks while connecting them with school district teaching opportunities.

TeachFX supports teachers by providing instructional feedback on how to facilitate supportive, meaningful discourse with and amongst students.

Master Teaching Fellowship Program is a partnership between the Highlight School District and Western Washington University to support bi/multilingual professionals to become certified teachers with secondary and bilingual endorsements.

DREAMS OF THE FUTURE

A Virtual Lab

In imagining their child's future learning environment, parents imagined a lab, a "pod," next to the classroom where students could use virtual and augmented reality to learn how professionals in different fields do their jobs. For example, students could conduct virtual surgery in this immersive VR environment, with a professional surgeon either present in-person or virtually, helping them navigate decisions. They described this as a safe and low-stakes way for their children to learn complex activities hands-on.

—Imaginings from lived expert workshops

Developing relevant experience opportunities that utilize mathematical reasoning that students can use to create or find fulfilling, sustainable employment.

How might we develop communities that encourage students to apply their mathematical reasoning, while creating opportunities for skill building, pathways to higher education, and space for students to thrive in the future they will experience?

> ***Caregiver:*** *"As a 17-year-old, a student could be learning skills that are helping them function like a full-blown adult…they're taking high-level technical courses that they can build within their community and understanding what their career options might be."*

Indicators

Availability of a variety of apprenticeship programs across all fields for students in middle and high school that is integrated back into their interdisciplinary math learning in school.

Actions to get there

- Co-design workforce and interest base apprenticeship opportunities with students, caregivers and employers across a variety of fields to provide exposure to different opportunities and skills.
- Develop and implement pathways to ensure seamless transition for students to other employers, entrepreneurship, or postsecondary institutions based on student interest. This can include:
  - Apprenticeship quality assurance standards
  - Postsecondary class credits
  - Financial support to pursue higher education etc.
- Develop and implement training for apprenticeship mentors to nurture student interests and help students navigate career or higher education pathways based on their interests.
- Create state level policy, funding, and private and public sector partnerships, for the development of robust apprenticeship programs.
- Develop partnerships with postsecondary institutions to ensure skills and knowledge transfer to certifications, degrees or other relevant pathways.
- Pilot apprenticeship program for high school students in BL-LI focused schools. Gather student feedback for continuous improvement.

Indicators	Actions to get there
Districts are supported through a variety of ways to build, maintain and improve apprenticeship programs.	• Fund BL-LI grassroot organizations design and implement technical assistance for districts and employers around apprenticeships. • Funding pools are available for district leaders to visit and learn from exemplar sites.
Student learning across the classroom and in apprenticeships is connected with a focus on enabling metacognition and a sense of belonging.	• Develop opportunities for students to learn, reflect and apply learnings across school, life, and their apprenticeships. • Fund and develop open source platforms with APIs for communication and personalization across industry and classroom to coordinate student learning, credentials, etc.

BRIGHT SPOT

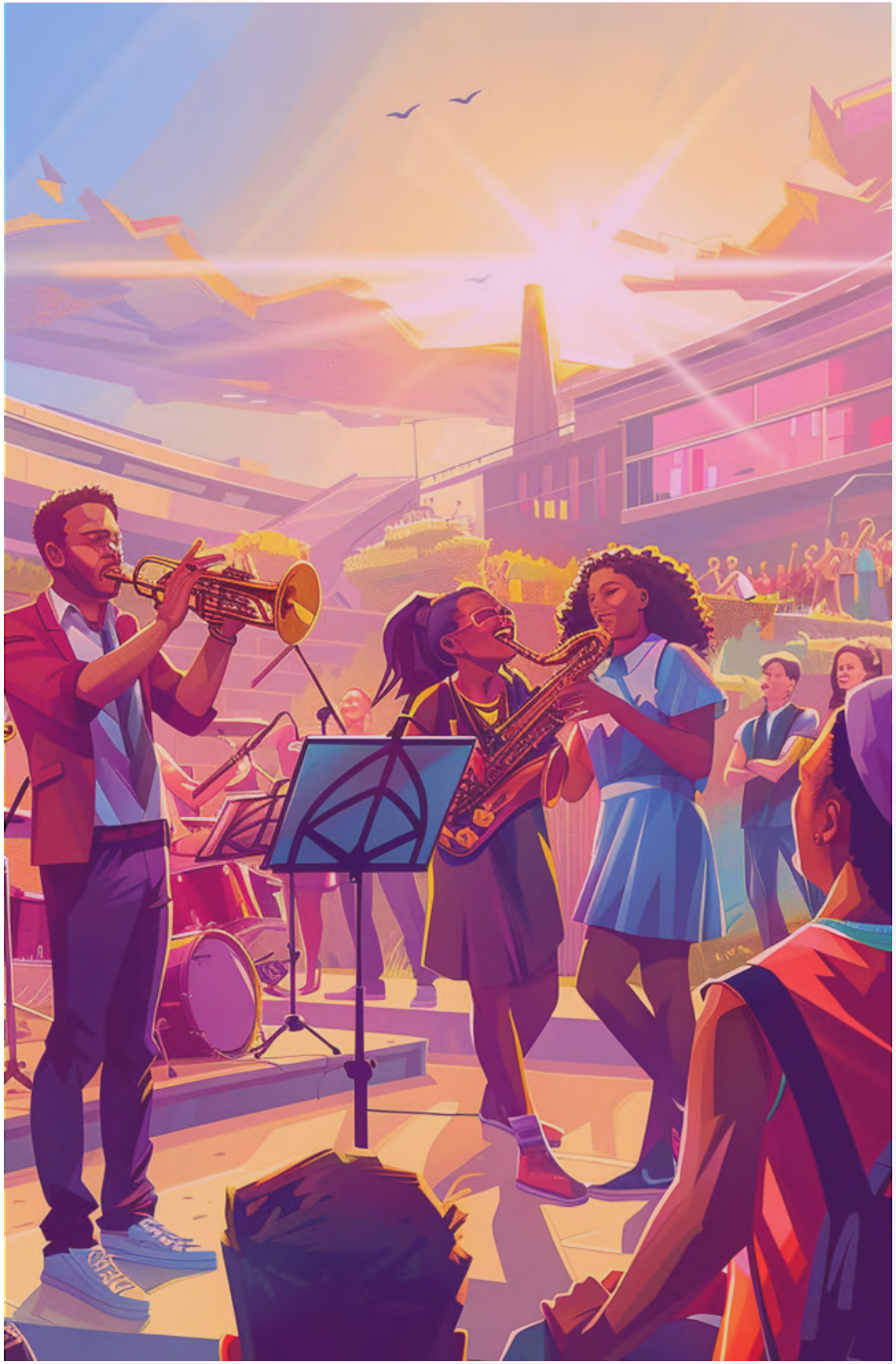
Black in AI is a collective that actively pursues avenues for Black researchers and students to participate in and build careers in AI through providing scholarships, mentorship, and advocacy.

DREAMS OF THE FUTURE

Band Practice

When a group of teachers were prompted to think about what the school day of the future would look like, one teacher said that the teacher would leave after school and go to practice with her band. They laughed about the idea of actually having time for hobbies, then had a great discussion about what it would mean for teaching to be distributed among the community and not feel like it completely falls on their shoulders as classroom teachers. They imagined industry professionals coming into the classroom to do project work with students on a regular basis, with students spending some time in classrooms but also in industry and community environments.

—Imaginings from lived expert workshops



Developing math curriculum that grows students' critical consciousness through supported and evolved teacher pedagogical practices that are focused on learning together.

How might we reimagine math curricula and pedagogy to elevate student autonomy and power while raising their critical consciousness?

Indicators	Actions to get there
New math curriculum is interdisciplinary, enables deep learning of concepts to enable student proficiency, engages and values student identities, mathematical thinking, cultural, linguistics, and community-based knowledge. Mathematical pedagogy connects to students' intersectional identities and creates space for sharing authority with students to be authors of math knowledge. Includes different ways of creating and expressing math knowledge and focuses on leveraging those ways to understand and investigate the world around them.	• Co-design new math curriculum with BL-LI students, BL-LI equity leaders, BL-LI math out-of-school programs, educators, and caregivers. • Pilot new content with select school districts to gather feedback from all stakeholders. • Iterate and implement curriculum at scale.
Students are active co-designers of new tools developed to measure mastery of math concepts.	• Co-design new culturally relevant assessments that measure learning, student motivation shifts, and concept mastery on an ongoing basis at the local, regional or national level. – Insights are used to provide TA to districts from a cultural competency and interdisciplinary lens.

Caregiver: *"Students need to be taught the skill of exploration. How do you capitalize on using math for the greater good? What can I use math for? They need the space for exploration to really apply math concepts."*

BRIGHT SPOT

Coherent Math is a standards-aligned, culturally relevant math curriculum that also includes reflection and connection to student prior knowledge.

Indicators	Actions to get there
Students are active co-designers of new tools developed to measure mastery of math concepts. (Cont.)	– Pilot these new measurement tools with the intention of replacing high stakes standardized testing. • Co-design and implement student surveys that gather input on educator and school practices that are used for continuous improvement at the classroom, district and state levels. • Develop and implement technology-enabled analysis of student learning and interdisciplinary math application. – Support schools and district access technical assistance to improve practices based on results. • Provide students with access to visual data to assess their own progress and learning.
BL-LI students and educators are key stakeholders in the design implementation of a new math curriculum.	• Development of EdTech specific policy to ensure that developers actively engage, support and compensate BL-LI students and educators to inform, design, and implement the products as equal partners in the work and not just "consumers". • Develop and implement new cross-sector funding models for BL-LI technologists to co-design products with BL-LI students for culturally relevant curriculum and practice. • Develop large language models (LLMs) focused on culturally responsive math, reviewed by BIPOC math experts. • Implement and measure the impact of the new math curriculum in select districts.
Students, educators, and caregivers have strong positive relationships with math.	• Design and implement asset-based marketing initiatives to address teacher, student, and caregiver mindsets and perspectives of math knowledge, narratives around math, and who society sees as mathematicians.

BRIGHT SPOT

Connected Mathematics is a curriculum that connects middle school concepts to other relevant disciplines.

Ethnomathematics curriculum by the University of Hawaii is a library of content organized by different age groups that provide educators with student-relevant content.

Investigations 3 is a K-5 math curriculum that is hands-on and can be taught in a variety of modalities (blended, digital, or without technology), focuses on relevancy, and provides resources for educators to consider equity in their classroom.

TODOS: Mathematics for ALL – Education for All and the National Council of Supervisors of Mathematics (NCSM) have released a joint position statement on Social Justice in Mathematics that identifies opportunities and has action steps for implementation.

DREAMS OF THE FUTURE

Food tech

Prompted to consider the technologies of the future that might be available in schools, one teacher suggested that learning about food technology would be imperative. With a changing climate, they imagined a greater focus on wellness for students, and how they might create classes that interconnect agriculture, math, and nutrition science with how to develop new types of foods that could withstand changes in the environment.

—Imaginings from lived expert workshops

Designing flexible learning environments that give students and teachers more opportunities to integrate math as an explorative practice.

How might we enhance the flexibility of learning environments so that math can become both a central focus and explorative practice for teachers and students?

Indicators	Actions to get there
Students are learning math in a nature-centric environment.	• Develop and implement state-level policies with an emphasis on outdoor for all. • School districts develop and nurture strong partnerships with local outdoor learning organizations.
Math teaching and learning is trauma-informed and addresses math and societal traumas for both student and educator.	• Support trauma-informed BL-LI community organization in running student, caregiver, and math educator training on adverse childhood experiences and their impacts on the body and learning. • Create cross district support for educators to identify, process, and overcome past math traumas. • Create, fund, and support BL-LI organizations focused on student advocacy to create and implement programs within schools across K-12 age group to support student agency and advocacy.

Indicators	Actions to get there
Emerging technologies, such as augmented reality (AR) and virtual reality (VR), are available for experimentation, learning, and creativity in schools that predominantly serve BL-LI students.	• Districts fund and maintain learning labs that experiment with implementation of different technologies with students for classroom learning and career skill development. • Train educators to implement emerging technologies equitably across student groups for creativity. • Support and develop myriad AR and VR applications that support student career interests and enable for practice (such as surgery) in a safe environment.
Educators have time to experiment teaching concepts.	• TA support to help districts manage strategic staffing and budgeting for teacher collaboration across disciplines. – TA for districts and educators to adapt to the time required for learning different concepts. • Implement and scale tools and training for educators to customize teaching for learner variability.[54] • Implement System Strategy Return of Investment measure to better understand if strategies are having intended outcomes on students.[55]
Caregivers are informed and engaged in student math learning.	• Reduce barriers for engagement for caregivers by creating respectful bi-directional feedback pathways and math specific resources in multiple languages and modalities (online, physical) for them to understand how and what their children are learning in mathematics. • Create caregiver-specific content to help caregivers build on their personal, communal, historic, and cultural mathematical knowledge. • Strengthen partnerships with faith-based and community organizations that provide additional academic and socio-emotional supports for children in the communities. – Create opportunities for meaningful two-way conversation between educators and the community organizations.

BRIGHT SPOT

Out Teach helps teachers teach students in the outdoors. They have a quick starter guide.

DREAMS OF THE FUTURE

A family of communities

When asked to consider what schools of the future might look like, students considered a radical redesign that centered around their interests. They imagined an interdependent group of affinity-based student communities, each focused on an interest area such as dance, mental health, sports, or debate. The groups would work independently, solving problems utilizing core math, science, and technology skills—communicating regularly to ensure that each group and every student was learning optimally.

—Imaginings from lived expert workshops

Conclusion

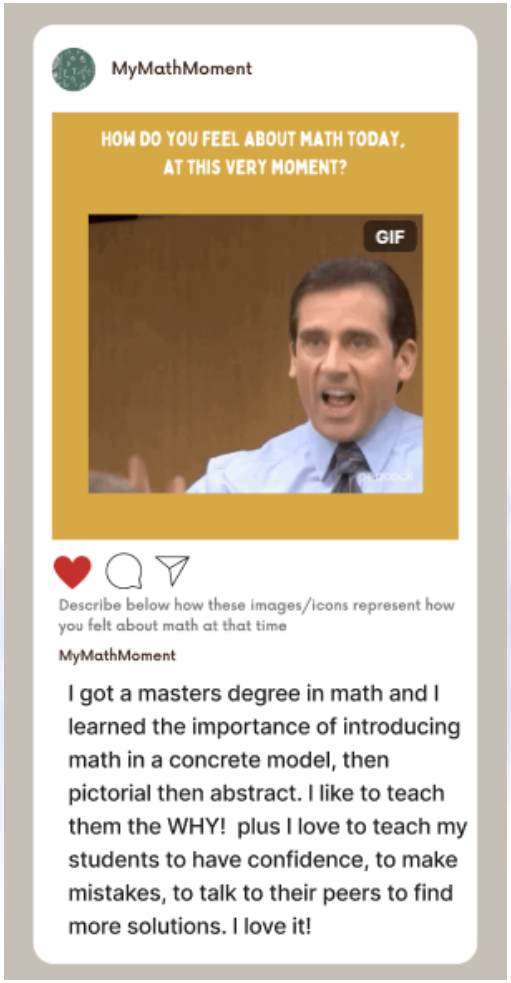
+ Making these visions a reality
+ Acknowledgements
+ References

Making these visions a reality

We are positioned at a unique intersection of time. We have access to historic and current information about the education system, not only from across the country but from around the world at our fingertips.

Education researchers, abolitionists, and mathematics researchers have developed bodies of work that not only show us what is working to support students furthest from equitable education but also what is not working for them. Additionally, we are on the cusp of change with technological leaps through advances in the field of machine learning such as advances in computer vision impacting the quality and application of artificial intelligence. While we will not know exactly what the future we will experience will be like, we have information from a variety of sources to tell us that it is going to look very different from our current experience. Continued impact from climate change, global economic shifts, pandemics, and shifting societal perspectives and norms will influence the future life, work, creativity, and stability. We can either allow the future to "happen" to us, or we can work to diligently shape the future we want to see—even with changes that might be out of our control.

Mathematics is a key component of thriving in the future. From daily tasks to designing the systems that will support and manage activities, tasks and other work, knowledge of math will support students to thrive in this future. How and what math is taught is not working for all students across K-12 today. We have the opportunity now to shift from making just incremental changes to innovating by reimagining possibilities for math education. We recognize that the constraints of tomorrow are going to look significantly different; however, we can be



Math moment submission from a teacher.

ready for them. This collaborative effort between KnowledgeWorks and Optimistic Design, supported by The Bill and Melinda Gates Foundation, is intended to do just that—to help stakeholders who have power in redesigning the system think out of the box. The work involved gathering information about possible futures through exhaustive trends and lived expert research coupled with co-creative imagining of math education in these possible futures with lived experts. We want these dreams to be realities, so we brought in SMEs with expertise in implementation, futuring, and policy across all aspects of the education system to help us find the steps needed to get to visions that lived experts co-created.

Access to high-quality education should be a fundamental human right to enable all students to thrive in their communities and the world. As designers, researchers, funders, and administrators, we have the opportunity to make this dream a reality.

Let's work together today for a better tomorrow.

"All that you touch you change. All that you change changes you. The only lasting truth is change."

—Octavia Butler

"As you enter positions of trust and power, dream a little before you think."

—Toni Morrison

Acknowledgements

Working towards the future of math education has not been a solitary task. We would like to recognize and thank the many individuals and organizations that collectively contributed to this project by providing their time, energy, thoughts, desires, feedback—and, most importantly, their dreams.

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Advisors
Aury Fernandez
Michole Washington

Cultural Moderator
Jodalys Hernandez

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Knowledgeworks
EdSolutions
ResultsLab

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The Bill & Melinda Gates Foundation

Collaborators
Debasmita Basu
NaKita Beaudion Lewis
Colleen Bolton
LaTonia Busby
Kayleen Cajucom
Jason Cameron
Mauricio Carabali
Andres Carter
Eddie Chabla
Tatiana Chalas
Cherish Coley-Bosley
Nichole Criminger
Grace Dillon
Tricia Douglas
Zena Fadel
Morgan Givens
Alyce Gresham
Daniel Harrington
Samiya Johnson Pigatt
Dawn Jones
Dave Kung
Eva Leung
Alondra Limon
Estibaliz Matulewicz
Amal Mohamed
Michael Molina
Miguel Molina
Judit Moschkovich
Maisha Moses
Saraswati Noel
Antonette Payne
Noel Price Perkins
Kathryn Procope
Curtis Taylor
Lawrence Udeigwe
Ismar Volic
Tricia Wildman
Alicia Williams

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Optimistic Design, a subdivision of Substantial, is a leading equity-centered design (ECD) and research consultancy. We form strategic partnerships across the education and social impact landscape to build transformative strategies and innovative digital products and services.