The Math Gap: Implications for Investing in America's Workforce

Power in Numbers
Advancing Math for Adult Learners

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Acknowledgments

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A Critical Math Moment for American Adults

The future is built on math. From algorithms to chemical composites to business models, **advanced mathematics** (algebra and above) undergirds human progress and economic growth now more than ever. Troubling research on the low skill levels of the American labor force has led policymakers to increase their focus on skill attainment and adult education.

In many ways, adult learners are the "new normal" student, and yet there is relatively little supply in terms of learning technology, course material, and educator support tailored to adult learning. Now, demand is growing for resources that will enable adult learners to more quickly attain advanced math skills to better prepare them for the demands of the workforce.

The Math Gap

Upskilling around mathematics in particular has become imperative for future competitiveness. Already by 2004, more than 40% of skilled blue collar employees reported using advanced math on the job, while 94% of all jobs require some math skills.[1] The Bureau of Labor Statistics predicts four times the rate of job growth for math-related careers over the average job sector from 2014 to 2024.[2] Meanwhile, more than a third of adults in the United States have low math skills,[3] scoring below level one numeracy according to the OECD Survey of Adult Skills.[4] Numeracy is defined as "the ability to access, use, interpret and communicate mathematical information and ideas in order to engage in and manage the mathematical demands of a range of situations in adult life."[5] For international comparison, the U.S. ranks 24th out of 30 in OECD's Survey of Adult Skills in mean numeracy score.[6]

The Adult Skills Gap

Nearly 25 million adults do not have a high school diploma,[7] but by 2020, 65% of all U.S. jobs will require postsecondary education and training beyond high school.[8] Demand for retraining is growing: A 2013 Lumina / Gallup poll found that 38% of Americans without a postsecondary credential believe it is very or somewhat likely that they will go back to school to earn a college degree or certificate at some point.[9] And there is little time to waste: sometimes called "new collar" jobs, demand for skilled labor already outpaces supply in industries including advanced manufacturing, where an estimated two million jobs will remain unfilled as employers struggle to find qualified employees.[10] This skills gap threatens long-term American

competitiveness, leading to calls to not only revitalize early education, but to reskill American adults.[11] And this is not just a gap, but a fundamental mismatch of what's being taught versus what's in demand: "There wouldn't be 4 to 5 million unfilled jobs today if degrees worked," says former Michigan Governor John Engler, president of the Business Roundtable. "People are getting training for jobs that don't exist or aren't open, and skilled jobs are sitting unfilled."[12]

Such inefficiencies in the labor market are not only telling signs of future problems, but have dire impacts on Americans today. Low skill levels are tied to underemployment and unemployment, lower wages and reduced earning capacity, and even consequences for individual and public health. Demand for reskilling is already high: wait-lists for community college courses are long (16,000 people are on waiting lists for adult classes in Los Angeles alone),[13] thousands "show up" for online courses, and by 2014, already 40% of students in higher education were non-traditional adult learners over the age of 25.[14]

Funding Landscape and Measuring What Matters

Public Funding: To date, stakeholders across the public sector have taken steps to push forward the integration of technology into the adult classroom and reinforce the links between the classroom and the workplace. The Workforce Innovation and Opportunity Act (WIOA) has supported the use of technology to improve teaching and learning and to overcome challenges in the adult classroom. The U.S. Department of Education's Office of Career, Technical, and Adult Education (OCTAE) funded the *Open Educational Resources to Increase Teaching and Learning of STEM Subjects in Adult Education Project*, which curated and promoted OER for use in adult STEM education.[15] The U.S. Department of Labor developed the Career OneStop website, which organizes careers in terms of DOL competency models.[16] State-level credentialing projects like the Work Readiness Credential from the National Work Readiness Council have sought to further bridge the gap between the adult classroom and readiness for the workplace, with varying degrees of success.[17] Across all public sector efforts, broad goals include: increasing the number of adults served by the educational system, advancing learners along degree and career pathways, and stimulating innovation and experimentation around educational delivery.

Private Funding: Outside the public sector, relevant funders of adult education initiatives include: foundations (MacArthur Foundation, Joyce Foundation, Lumina Foundation and Kresge Foundation are just a few of the most prominent examples); nonprofits (such as Digital Promise); and professional consortia (including OTAN: Outreach and Technical Assistance Network and NCTM: National Council of Teachers of Mathematics), some of which are math specific. Across funding groups, WIOA (particularly Title II, specific to adult education) has revitalized energy and resources around supporting adult education. With federal directives in place to increase technology use in the classroom, funders are motivated to apply cutting edge research and to deploy new tools through classroom-level experimentation in the pursuit of best practices around implementation and tie them to outcomes. However, little of this broad experimentation has specifically focused on advanced math adult education.

Measuring What Matters: Across funding groups, a central area of need is demonstrating return on investment (ROI) for new initiatives, experiments, professional development offerings, and programs. ROI here is not measured in terms of capital returns, but by evidence of progress around key educational outcomes. Even programs that are highly successful from the perspective of the providers and students served can face shut-down if they do not meet ambitious internal thresholds for success set by their funders. What gets measured matters: it is incredibly hard to demonstrate success when metrics are based on top-level indicators of student achievement. Increased student retention, credentialing rates, and ultimately reduction in unemployment and underemployment are the holy grail of educational investment outcomes, but what one program or experiment can hope to move the needle? In many cases, measuring outcomes in terms of metrics like student/teacher satisfaction, course completion speed, or improved outcomes on specific assessments may be more attainable. Developing appropriate metrics around the outcomes of experiments in advanced math education in particular is an area of need for relevant organizations.[18]

A Call for New Approaches

Technology offers a promising fix to many of the challenges within adult education, but is not a silver bullet. It is not a cure-all for complex issues around funding, degree pathways, and teacher preparation, but presents promising solutions to many systemic challenges around access, resourcing, and contextualization.

Given the ongoing growth of technical careers and demand for high-skill labor, there is a particular need for more technology to increase and quicken access for adult learners studying advanced mathematics. Math presents acute barriers for many learners; confidence, contextualization, and learner mindset are key to increasing math skills. Market signals require meeting learners (and educators) where they are.

This report will showcase the potential for technology to enhance the teaching and learning of advanced math skills to adults, providing nuanced guidance for funders and educational innovators. We will discuss key stakeholders, their needs, and opportunities for investment to capitalize on the potential of technology to better ready adult learners for the workforce. In particular, we will delve into areas of key need like contextualization of classroom resources and professional development for educators.

Following a review of needs for relevant stakeholders (employers, adult learners, and educators) and a discussion of technology's promise, we will introduce "three A's" of adult edtech: Accessibility, Adaptability, and Applicability. These encapsulate and represent many ongoing cross-disciplinary calls to tailor new tools and approaches to the needs of learners and the educators who serve them, ultimately laddering up to the needs of industry job creators. Several such efforts and technology development areas are particularly relevant to advanced math, and we will hone in on the example of open educational resources (OER), a parallel movement in education to leverage digital technology and open source licensing to extend educator wisdom.

The purpose of this report (and the forthcoming reports described below) is to capitalize on the intersection of grassroots resource development, technology innovation, and labor market demand for skills to inform the future of adult advanced math education.

A Critical Math Moment for American Adults

Key Takeaways:

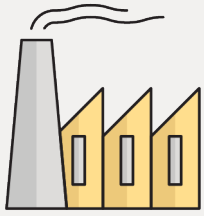
- American adults lag behind international peers in math skill attainment
- Advanced math competencies are increasingly crucial for national competitiveness
- Ongoing movements and new approaches in edtech are beginning to coalesce around increased demand for math skills and learning tools
- It is important to determine how to measure innovations and agree upon metrics that accurately reflect their value
- As a nation, we are in a critical moment, when learner and industry needs can inform educational resource development

About this Report

This document is the first in a series of three reports on the market serving adult learners of advanced mathematics. This initial report focuses on the demand side of relevant markets, including demand for advanced math skills, demand for new tools and approaches that meet learner and educator needs, and demand for teacher training to support deployment of new tools. Subsequent reports will focus on the landscape of relevant tools, and opportunities to improve efficiency in the markets serving adult learners, respectively. This document was funded by the U.S. Department of Education Office of Career, Technical and Adult Education under the project titled "Power in Numbers: Advancing Math for Adult Learners" (OER Math project), Contract Number: ED-VAE-14-D-0006/0004, and it includes input from adult education practitioners, researchers, and policy experts.

Stakeholders: "Variables and Constants" in the Adult Learning Landscape

In many ways, the stakeholder landscape around adult education is like a puzzle that doesn't quite fit together. It is a story of many initiatives and a missing piece: industry. Diversity abounds: employers note disparities between current skills and future needs, learners have different backgrounds and circumstances, and educators have varied levels of experience and availability. Compounding this complexity, though passion for adult education is high, resources tend to be low across all groups, and stakeholders come and go. Students cycle in and out of classroom environments across inconsistent and uneven providers and educational experiences. Some educators teach adults only part-time, while others devote their entire careers to adults and other non-traditional students (with impacts on educational outcomes).[19] As in other areas of education, programming must periodically realign with new standards and budget realities. And there's an absence of employers from many initiatives and conversations. But across these groups, there are vast market opportunities to serve the unmet needs of adult learners and the educators and providers that serve them.



Employers

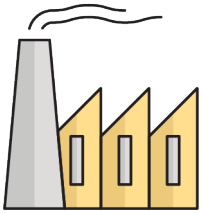
Centers of demand but disconnected from the conversation

Learners

Striving for skills but facing obstacles

Educators

Short on professional development, not passion



Employers

Key needs: Workers with skills aligned to the jobs of the future, and opportunities to shape their training

The employers and job creators who ultimately dictate which skills matter most in the workforce are providing increasing resources and funding for adult education and retraining. These efforts are supported by federal directives that increasingly strengthen ties between industry and adult education. However, with relatively few opportunities to shape national workforce development initiatives, industry often undertakes retraining efforts internally.

The Business Case for Retraining

While some employers may fear losing newly skilled employees to competitors, there is much evidence that corporate retraining and continual learning efforts deliver returns.[20]

The bottom line for businesses is a need for employees with more skills. Employees must learn to quickly adapt to new software, approaches, and technology areas. By some calculations, the shelf-life of the average in-demand skill is now less than five years, and many of today's fastest growing job categories did not exist five or ten years ago.[21] Industries like advanced manufacturing and healthcare are on the cutting edge of new tools and techniques. Meanwhile, processes and roles in most service industries like law, accounting, and finance are shifting to accommodate artificial intelligence and automation approaches that redefine human job functions. Specifically, automation of more basic job functions is increasing capacity and refocusing human labor around more advanced tasks, mathematical and otherwise.[22] These trends will only accelerate in the coming years.

Many major employers in math-relevant fields like automotive, heavy machinery, and advanced manufacturing sponsor training institutes to ensure learners graduate with the skills they'll use on the job, such as the Lincoln Electric Welding School.[23] Starbucks, meanwhile, surveyed its employees to find that an overwhelming 80% desired upskilling support as a formal benefit.[24]

Industry Needs a Louder Voice in the Skills Conversation

The needs of industry as a stakeholder group center around an educational system that better shepherds people to career pathways. State-adopted content standards have tried to zero in on the most important functional math skills, but employers have a role to play in this equation. According to one study, while 96% of educators believe they are delivering workforce-ready students, only 11% of U.S. employers believe this to be the case.[25] In one survey of manufacturing executives conducted by the National Association of Manufacturers, 80% of respondents noted not being able to find workers with the critical thinking and technical skills modern manufacturers need to succeed.[26] There is evidence that employers are already stepping up to assume some responsibility for shaping the skills conversation. Lockheed Martin, for example, has identified the top 20 jobs over the next five years that do not currently exist, and plans to use that research to map out likely impacts

on curricula and educational delivery.[27] But the nation's biggest employers cannot carry the torch alone: increasing opportunities to connect adult education providers and medium-sized local businesses will be key to increasing the employability of program graduates.

Federal efforts invite industry to play a more central role in the national skills and educational programming conversation. A prime example are the WIOA Performance Indicators, the metrics used to judge the success of adult education programs. Moving beyond retention rates and student satisfaction, indicators are becoming more and more tied to employment outcomes. One such indicator, "effectiveness in serving employers," while presenting a measurement challenge for program administrators, specifically ties program funding to employer satisfaction.[28] Such statutory mechanisms represent a key opportunity for employers to inform programming in the formal higher education system. Employer calls for candidates with STEM skills, which include math, are well-known, but researchers note a gap around industry defining advanced math skill needs in more detail.[29]

Adult Learners

Key needs: Learning opportunities, and accessible, relevant content for skill building

Adult learners with low math skills require opportunities to upskill and align themselves with the demands of the labor market. In order to attain the advanced math skills that are increasingly in focus, they first need access to adult education programs, and then need content and resources (and instructors to deliver them) that are appropriate for their ability level and background.

Adult Learners and Low Skill Adults

The population of adult learners in the U.S. is vast and diverse: as mentioned, more than 36 million adults have low levels of skill attainment, and nearly 25 million lack a high school credential.[30] The effects on individual earnings, career advancement prospects, and job performance are widespread. For example, in the service sector, some 74% of employees have low numeracy skills, but 50% need to use math on the job.[31]

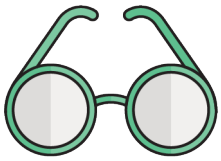
Not all low skill adults show up in the formal education system, but among adults who do participate in learning activities, education predicts participation: adults with a high school diploma and a paying job are more likely to seek learning experiences, suggesting that students with the most need face financial, psychological and physical barriers to access that prevent them from showing up.[32] Indeed, time is a central constraint for adult learners, many of whom work more than one job and/or have family responsibilities that make the classroom environment inaccessible. Among adults who lack a post-secondary credential and plan to seek further education, 25% are looking to earn credentials entirely or mostly online.[33]

Barriers and Special Populations

There are close linkages and large overlaps between low income, low education and low employment levels, which contributes to time and resource constraints for many adult learners. For example, of undergraduate students over the age of 25, a substantial percentage are low-income: 40% of adult students enrolled in higher

education have annual incomes less than $25,000. Income is not the only barrier to education, but degree attainment for low-income adults is particularly low, with six-year completion rates of about 7% compared to more than 40% for traditional students over the same time period.[34]

Special populations of adult learners also face unique challenges learning math. Incarcerated adults (1.5 million adults were in the prison system as of 2015)[35] are one of the highest-need populations and a huge area of opportunity: correctional education is linked to dramatically lowered rates of recidivism.[36] While learning anxiety can affect all adult learners, self-efficacy, which is related to confidence and perception of ability, has been shown to be especially indicative of success among incarcerated learners.[37] Another group are English language learners: in 2007, 46% of participants enrolled in state-administered adult education programs were taking English as a second language (ESL) classes.[38] Language proficiency is a hurdle in any learning endeavor, and advanced math courses geared toward ESL learners are rare.



Adult Educators

Key need: Relevant professional development resources

Adult educators are rarely lacking in enthusiasm or appetite to embrace new methods to deliver content and enhance their teaching. They require support from programs and administrators to fund professional development, empowering them to fully make use of available classroom tools and resources.

Demographics of Adult Educators

Across disciplines and age levels, student engagement is closely tied to teacher engagement.[39] When mathematics is taught well, students achieve better outcomes.[40] But who are the educators dedicating their time to teaching adults? Compared to their K-12 and higher education compatriots, adult education instructors skew slightly older and many are part-time and/or volunteer.[41] Depending on the institution in which they teach, educators may or may not be paid for lesson preparation or resourced to purchase classroom supplies, and are required to serve as case managers for high-need students. Passion for the craft is in strong supply among adult educators, and professional associations and conferences like the Commission on Adult Basic Education (COABE) and the math-specific Adults Learning Mathematics (ALM) demonstrate the connectivity and commitment in this group.

Adult educators tend to be well-educated themselves: nearly 60% have master's degrees, and another 10% have attained a doctorate.[42] The story these numbers do not tell, however, is the uneven preparation across educators for the realities of the adult educational classroom. Required credentials and qualifications vary across states,[43] and experience and expertise varies across both math content knowledge and expertise in andragogical approaches. Some educators have extensive preparation in both math and education, others have extensive preparation in education but not as much in math, while still others may have earned degrees in science or other relevant areas that result in strong math ability but little guidance in adult

learning theory or formal mathematical learning approaches. There is evidence that this unevenness across levels of preparation has significant impacts on educational outcomes.[44] Levels of preparation among adult learners are also varied, resulting in mixed-ability advanced math classrooms. Most adult learners access advanced math through remedial education, but only 35% of students who finish all their remedial classes go on to pass an introductory college-level math class within three years.[45] This lack of uniform preparation of incoming adult learners places a greater burden on educators.

Professional Development

Ongoing professional development (PD) is a key need for math educators across the country, regardless of student type. Mirroring student achievement, math teacher preparation in the US tends to be less comprehensive and less effective compared to international benchmarks.[46] The PD opportunities for educators of adult learners are particularly stark; relatively little PD is designed particularly for the adult educational environment. Training instructors in applied adult learning theory,[47] social and emotional learning,[48] learner mindset,[49] and other important aspects of effective math education is one of the most crucial factors in elevating math skills for adult learners. Compounding this market gap, there is variation across states regarding PD requirements, and a lack of consensus on what constitutes appropriate PD content.[50]

Technology-oriented PD is also in demand: tactical upskilling for teachers around digital literacy, integration of new tools and approaches, and use of open educational resources (OER). Though its grassroots popularity is surging, most educators still don't know how to use or find OER. According to Chonda Long of NCTM, those educators who do actively contribute to the available pool of adult-oriented OER often develop proprietary PD content as well, a revenue stream that can support offering classroom resources for free. Such business model experimentation is necessary, but PD is just as often offered through professional organizations, technology companies, educational publishers, and through more grassroots means. Ad-hoc networks of educators form online communities of practice through Twitter and blogs that effectively function as sources of new skills and information.[51]

Retraining Is Crucial for Educators, Not Just Learners

Professional development is thus a large category of need among adult educators, but many educators have anxiety about incorporating technology in the classroom.[52] Teachers want to own the process of implementing new approaches,[53] but often need support and training to make the best use of new tools and resources.[54] PD needs may be particularly high for advanced math educators, who often have varied level of math teaching expertise, and who may or may not know the importance of contextualization, learner mindset and other crucial factors. PD needs extend beyond digital literacy, andragogy, and educational technology training; as discussed in the box above, educators in the adult classroom are not only teachers, but in many cases must also provide case management and continuity across educational experiences, and navigate "multi-level classrooms" in which students have different levels of knowledge.

Stakeholders: "Variables and Constants" in the Adult Learning Landscape

Key Takeaways:

- While many employers invest in internal retraining efforts, industry job creators have too often been left out of the public skills–development conversation
- Adult learners face learning barriers in terms of time, confidence, and resources, but demand for retraining far outpaces supply
- Though they tend to be under-resourced, adult educators are a passionate and diverse group who are eager for additional professional development opportunities

"Solving for X" Through Tech

Technology is no panacea for education, but sufficient evidence regarding its potential impact on key educational challenges has led to legislative encouragement for an increase in educational technology use in adult education through WIOA. Under Section 223 of WIOA's Title II, states may use funds for the implementation of instructional technology as well as for professional development to support its use.[55] In many cases, though resources for experimentation are relatively low, demand is high. Adult ed administrators and educators alike are excited about technology's potential, and eager to experiment with its use in the classroom, with 86% agreeing technology solutions can effectively support adult education instruction.[56] There is, of course, a valid critique to be made of "solution-first" technology development and implementation, and the necessary work to align educational technology development to learner needs, classroom realities, and employers' desired skills is in early stages. Nonetheless, many technology areas and aspects of digital approaches show strong promise to impact specific challenges in adult education.

The Potential of Technology to Meet Key Needs in Adult Education:

Need	Near-term Tech Remedy	Future Tech Opportunity
On-demand learning content	Online learning content	Mobile learning content
Affordable content and opportunities	Open educational resources	Open enrollment certificate and degree pathways
Effective experiences for adult learners	Online tutoring	Adaptive learning pathways
Motivation for learning	Contextualization	Industry-supported skill badges
Accessible resources	Section 508-compliant digital tools	Personalized content delivery
Seamless educational experiences	Learning management systems	Credit for non-classroom learning
Personalization of learning	Self-guided modules	Adaptive curriculum "playlists"
Engaging learning experiences	Contextualized learning	VR/AR simulations
Local access to experts	Virtual meetings	"Intelligent" chatbots
Digital literacy skills	Instructional videos	Agile and intuitive digital tools
Awareness of learning opportunities	Social media	Predictive analytics
Professional development of adult educators	Webinars	Training simulations
Better measurement of educational outcomes	Data capture and sharing	Frictionless assessments

The potential outlined above, combined with demand for reskilling from adult learners and low-skill adults, represents a compelling market opportunity for technology companies, educational publishers, and resource developers. Though resources tend to be low, entrants are rushing to meet demand from learners across age levels. We are in a critical moment, when the stakeholder needs discussed in the previous section can and should influence this ongoing development.

The Ecosystem for Adult Education Experimentation

Because of funders' significant role in innovation in adult education, knowledge capture and sharing is key to progress. Policymakers are attuned to research findings and must rely on the conclusions of academics and researchers to shape statutes and standards, but funders are the main conduit through which these findings are translated to experimentation on the ground. While most research, experimentation, and funding goes to the K-12 environment, there is increasing activity in the adult education space, as evidenced by initiatives from groups like Digital Promise and the Joyce Foundation. Such programs that support classroom experimentation around new approaches like digital badging, linked learning, flipped classroom,[57] open educational resources, and other models are a major contribution to the field of adult education.

Math Learning Technology

A new and important area of brain science shows that when we work on any mathematics problem, including basic arithmetic, five different pathways in the brain are involved, two of them visual. Our brains want to think visually about math, and improved math achievement comes about when there is more communication between areas of the brain. Presenting math visually also provides more opportunities for students to think creatively about math, and to engage with mathematical ideas deeply and positively.[58] This suggests that visual delivery mechanisms, including videos, animations, video games, and immersive environments, could aid in advanced math education.

A 2011 position paper from the National Council of Teachers of Mathematics lists additional relevant content-specific technologies including: computer algebra systems; dynamic geometry environments; interactive applets; handheld computation, data collection, and analysis devices; and computer-based applications.[59] Video-based lessons, interactive game-like experiences, and good old-fashioned puzzles are additional examples of effective math tools. More recently, math educators have honed in on open educational resources (OER), which can be delivered through higher- or lower-tech mechanisms, as a particularly promising innovation.

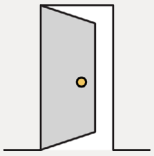
Benefits of OER for Adult Learners

Reduce Cost

Increase Efficiency

Improve Instruction

Encourage Contextualization



Expand Access & Equity

Open Educational Resources

Open Educational Resources (OER) are teaching and learning materials that reside in the public domain or have been released under an open license that permits their free use and re-purposing by others.[60] They can be revised, remixed, and redistributed, and they embody the potential of the "three A's." OER are openly licensed and freely accessible to anyone, and are adaptable and customizable and can therefore be made applicable to learners' needs and contexts.

OER represent a pragmatic and low-cost resource for a resource-constrained environment. Rather than relying on high-tech approaches and thus limiting the universe of for those developing solutions, OER enables anyone to become a creator of educational content.

Benefits

For teachers

- Better content mastery through creation and revision
- Informal professional development
- Access to a community of OER creators and users
- Flexibility to customize for multi-level classrooms

For learners

- Personalized and tailored learning materials
- Promotes engagement and persistence
- Lower costs

Outcomes

Perception

- OER do not deliver equivalent learning outcomes compared to traditional materials
- OER cannot deliver an equivalent or satisfying learning experience for students
- OER require high technical expertise from instructors

Reality

- Across studies of 17,000 students, 93% saw equivalent or better learning outcomes when using OER[61]
- More than 60% of educators and students agreed that OER increased student satisfaction with the learning experience[62]
- Many OER are low-tech and require basic only computing skills

Key OER Stakeholders and Roles

Employers
Inform content development

Learners
Use and provide feedback

Educators
Create and contextualize

A common concern over OER usage is that integrating OER requires both levels of digital literacy and internet access among instructors and students that is unrealistic. In fact, while 84% of American adults use the internet, the proportion among populations less likely to use the internet is surprisingly high: 58% of senior citizens and 78% of rural residents use the internet.[63] While quality of access and internet speed vary widely, most OER are relatively low-tech and can be downloaded for offline use.

OER come with their own design considerations around ensuring equity. In order to serve the needs of learners and classrooms in low-resource environments, scholars recommend OER be easily translatable, allow the option of being read aloud, be licensed with no restrictions, and be printable and readable, just to start. These seemingly simple design choices begin to frame the gap between what some call the "tech elite" and "tech poor."[64]

"Solving for X" Through Tech

Key Takeaways:

- Digital technologies and other new approaches show promise in addressing many of the unique and pervasive challenges in adult education
- Adult education represents a massive market need, inviting increased participation from edtech developers, publishers, and resource creators
- Policymakers, funders, educators, and providers must coordinate to translate academic research findings into classroom experimentation with new tools and technologies
- Following promising research findings, we are in a period of rampant experimentation around things like linked learning, digital badging, blended learning, and other efforts to better prepare students, but much of it is focused on K-12 education
- Advanced mathematics is a particularly promising area of development for edtech, and though few solutions have been designed for the needs of adult learners, tools like graphing calculators are already in widespread use
- Particularly relevant to advanced math learning are technologies that engage visual pathways in the brain, those that enable better contextualization of learning, and those that increase student confidence and engagement

Critical Considerations for Adult Edtech

Sustained investment in the adult education space requires comfort with failure as well as an appetite for success, and it can be hard to demonstrate results at scale. However, learning what works and what doesn't is happening constantly, through ambitious but pragmatic experiments across adult learning environments nationwide.

Technical Capabilities, Equity, and Access Remain a Hurdle

It is first important to note that across technology areas, digital literacy and equity continue to be barriers to access for some of the most underskilled adults.[65] The same barriers affect many adult education classrooms, many of which lack technology budgets, internet connections, and digitally fluent instructors. Some 45% of adult educators have only occasional access to computers at the program site, if at all.[66]

Still, the overwhelming majority of Americans[67] across ages and ethnicities,[68] and including adult educators,[69] are comfortable navigating the internet and associated digital tools. Mobile access is expanding across American adults, and an uptick in "smartphone-only" adults — those who own a smartphone that they can use to access the internet, but don't have broadband at home — demands mobile learning approaches.[70] Some 94% percent of lower-incomes families have some kind of access to the internet, but 23% of those families (and a full third of families living

below the poverty line) rely on mobile-only access.[71] Notably, 37% of adults without access to high-speed internet surveyed by Pew in 2015 reported that lacking broadband at home was a major disadvantage for learning new things that might enrich their lives, up from 23% in 2010.[72]

Limitations of Expanding Access through Online Education

Some tech experiments in adult education are directed and intentional, such as those funded by philanthropic efforts and groups like Digital Promise. Others occur more naturally through forces of market disruption. The latter case is demonstrated by distance learning[73] gaining momentum as higher education enrollments decline[74] and as adults represent an increasing percentage of higher education students.[75] This rapid adoption, even in absence of clear credentialing pathways, is a direct market response to learners' need for flexible, low-cost approaches to gaining new skills.

But it is not clear that distance learning approaches are meeting the promise of expanding access to meaningful benefits of education. Retention remains an issue for distance learners of all ages, hovering around 10% or less for most Massively Open Online Courses (MOOCs).[76] Online education typically lacks a social dimension, and social connectedness is a key facilitator of learner persistence.[77] There is also growing evidence that online education is a less effective teaching mechanism than face-to-face instruction, though it may have other benefits. For example, one study found that high school learners of advanced math who took online remedial courses fared worse on credit recovery assessments,[78] and learning math may be particularly difficult online.[79]

No Simple Solutions in Advanced Math or Adult Education

Even tools that genuinely make math easier are not without concern. Along with smartphone availability comes an always-accessible calculator, which critics charge can be as much of a crutch for students as they are an aid. And there is evidence that tools designed to teach math, not just enable easier computation, have limited utility as well. In 2007, when Congress commissioned a study into the effectiveness of 16 of the best reading and math learning software packages as selected by experts, the National Center for Educational Evaluation and Regional Assistance found their use did not have a measurable effect on test scores.[80] Math apps and games have flooded the market in recent years, but rather than provide students with a productive and visual experience of math, most are relatively low quality and replicate unsuccessful approaches to teaching math, such as closed questions with speed pressure.[81]

Broadly, most failures in adult edtech can be traced back to design that does not meet the needs and constraints of learners. Tools need to be contextualized and take into consideration the learner's needs and past experiences.[82] And, ultimately, face-to-face instruction may still be a better option for a wide variety of learners. Good educational tools should therefore not seek to replace in-person teaching, but enhance and/or extend it.

Critical Considerations for Adult Edtech

Key Takeaways:

- Barriers around digital literacy and equity pose challenges for adult education classrooms and would-be distance learners alike
- Smartphone penetration is high, and mobile learning remains a key white space of innovation
- Distance learning is growing in popularity, but retention remains an issue, and early evidence suggests online learning approaches are neither particularly effective nor engaging
- When it comes to teaching and learning advanced mathematics, technology can help or hurt
- Design considerations may be the most indicative in adult edtech development: tools must be tailored to the particular needs and circumstances of adult learners
- The benefits of face-to-face instruction have not been supplanted by technology. Edtech ideally enhances or extends the classroom experience, rather than seeking to replace

"Three A's" of Adult Edtech: Accessibility, Adaptability, Applicability

Much has been written on design considerations for educational technology, but little focuses on the needs of adult learners and the challenges of the adult learner classroom. These "three A's" of good edtech provide a high-level overview of the many considerations that resource developers and tool creators must take into account when designing for the adult education market, and learners of advanced math in particular.

Accessibility

- Designing for adult learner needs
- Digital equity
- Digital literacy
- Curation and discoverability of resources
- Usability (designed to reduce friction)
- Catering to learners with disabilities

Adaptability

- Flexibility to adapt to particular circumstances
- Integration of technology in the adult classroom
- Professional Development for educators
- Pedagogical/andragogical approaches
- Reusability (licensing)

Applicability

- Learner mindset
- Competency based programs
- Contextualization of resources*
- Alignment with standards and career pathways
- Credentialing and degree pathways

**indicates a consideration explored in more depth in this section*

Accessibility encapsulates ease of access to tools, discoverability of resources, design considerations that ensure usability,[83] and the degree to which resources promote a frictionless or continuous learning environment. While standards that promote accessibility are common in the K-12 environment, subsets of adult learners face unique access barriers around digital access, equity, literacy, and disabilities that mandate special considerations.

Adaptability as a category subsumes considerations around how educators make use of new tools and approaches. The best resources are designed to be flexible enough to meet particular curricular needs and contexts, low-cost and reusable through educator-friendly licensing pathways, and can shift to align to relevant pedagogical or andragogical approaches.

Applicability refers to the relevance of learning content, the degree of alignment with career pathways[84] and credentials,[85] and the extent to which tools aim to impact learner mindset, not just learner knowledge. A huge push toward contextualization of learning is particularly relevant to adult learner needs and conditions for success.

Contextualization

A critical consideration in adult learning, and in advanced mathematics in particular,[86] contextualization is the recipient of increasing attention and experimentation. Fundamentally, contextualization is "an instructional approach connecting foundational skills and college-level content."[87] More colloquially, contextualized resources are those that ground educational content in relevant real-life scenarios or those that transmit content through the lens of functional job skills.

Contextualization itself is an umbrella term, and can describe competency-based programs, personalized approaches, curricula rooted in current events, and culturally relevant content. All of these are especially advantageous for adult learning.

Because of its hard-to-overstate importance in adult learner success, contextualization has become a proxy for quality in many conversations, but it is no more a panacea for education than technology itself. Contextualization should be thought of as one best practice in the development of new resources.

For example, it is important to look past the surface variable of "contextualized" or "decontextualized." A task can be topically contextualized while ultimately still just asking students to compute a formula. Educational innovator Dan Meyer recommends viewing appropriate contextualization through specific lenses: Is the work itself is on par with the work performed in real-world contexts?[88] Is the work novel? Does it involve an element of surprise? Is it comprehensible? Do students have autonomy in their relationship to the work and to their teacher?[89]

When content feels relevant and connects to topics the learner is familiar with, engagement and retention of knowledge improve.[90] Contextualization improves curiosity, perception of interestingness,[91] as well as the learner's drive to "puzzle it out."[92]

Types of Contextualization

- Contextualizing particular resources around particular skills
- Contextualizing curricula around career pathways
- Contextualizing learning according to learner mindset and experience
- Contextualizing programs to meet learner goals

Types of Contextualized Experiences

- *Ad-hoc contextualization:* Educators often must do their best to find and add the proper context for applying standard math concepts
- *Digital learning and blended learning:* Incorporating online learning tools and online research capabilities can improve the relevance of curricular material
- *Competency-based learning:* Programs that make use of competency models (like those developed by the Department of Labor)[93]
- *Problem-based learning:* Learning content grounded in realistic scenarios that require learners to engage in problem-solving, not rote memorization or decontextualized computation
- *Bridge programs:* Programs that aim to serve as a "bridge" between adult education and higher education degree programs, or between adult education and specific career pathways
- *Linked learning:* Programs that integrate academic, technical, and work-based components. May refer to learning that is linked to workforce opportunities and/or career standards
- *Specific resource contextualization pathways:* Approaches for contextualizing the content of particular resources, such as MERLOT's "teaching commons" for OER[94]

"Three A's" of Adult Edtech: Accessibility, Adaptability, Applicability

Key Takeaways:

- Accessibility, Adaptability, and Applicability: Three central components of educational technology designed for the needs of adult learners
- Within each of these "three A's" are specific design considerations, approaches, and evidence-based best-practices that can serve as guidance for educational resource developers
- Design considerations for adult learners center around grounding resources in adult learning theory and maximizing social connectedness
- Professional Development is a key constant need across adult educators, and math instructors may be in particular need of resources and support
- Contextualization has become a proxy for quality in educational technology but can be applied too loosely. Still, it is key to learner motivation and plays an important role in a range of promising approaches and program types that may better prepare adults for specific career pathways
- Alignment with career readiness standards is as important in adult education as in K-12; the main priority of adult learning is to advance learners along degree trajectories and career pathways. Industry needs to be an active partner in defining these pathways

Coming Together for the Future of Adult Math Education

Adult education is critically important for both individuals and society, but the current system — which serves just a small fraction of more than 36 million low-skill adults in the US — demands additional resources, development, and the research and application of best practices.

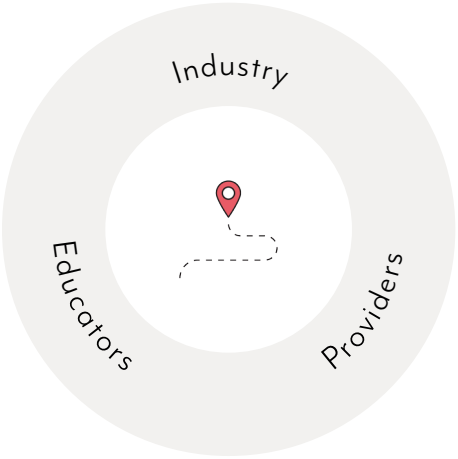
Calculating demand in the advanced math adult learning market requires reviewing current and future macroeconomic and job market prospects, understanding the needs and constraints of multiple stakeholder groups, and nuancing the conversation around key areas of technology development.

Through reviewing demand for tools, resources and approaches that meet the needs of adult learners of advanced math (and the educators who teach them), this paper has made the argument that demand for advanced mathematics skills and resources is growing, and that the needs of multiple stakeholder groups are underserved. Specific focus on topics like professional development, contextualized learning and alignment with standards and career pathways point to some of the biggest areas of need.

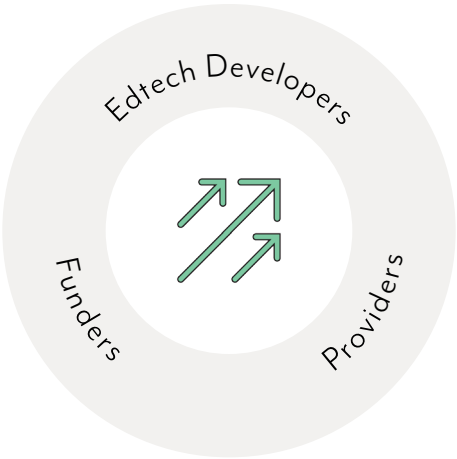
Subsequent reports will focus on the supply of relevant resources and market dynamics that govern development, adoption, and implementation of new tools. In the interim, we conclude our review of the demand side of the equation by issuing a call for increased collaboration across stakeholder groups.

While experimentation is ongoing, key stakeholder groups have an increasing role to play in collaborative efforts. The following wish-list represents groupings that would span silos to bring key expertise to bear on new programming and development.

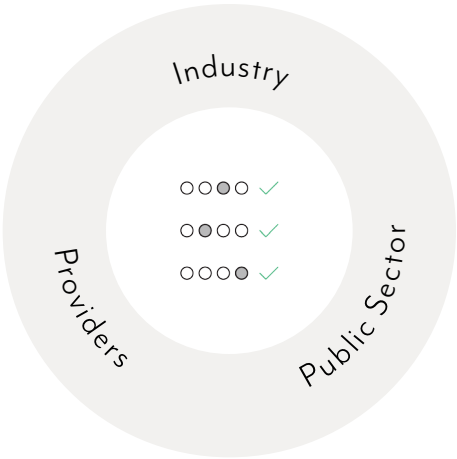
Contextualization



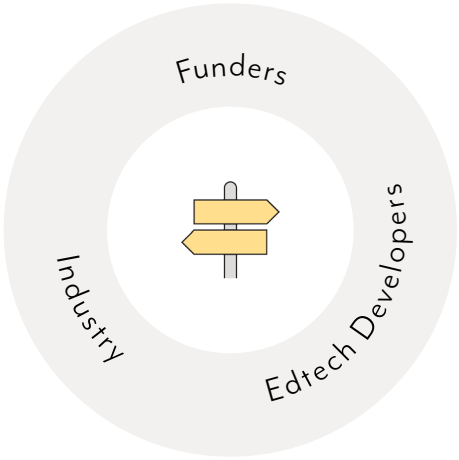
Professional Development



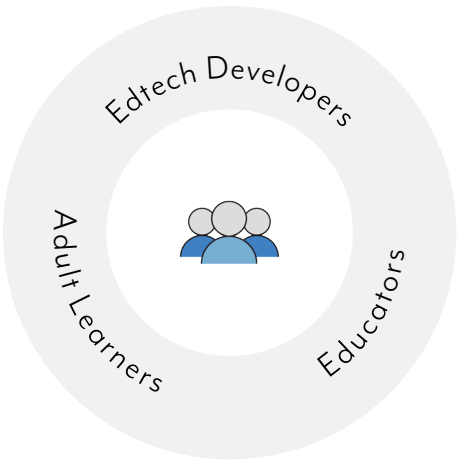
Skills and Standards



Career Pathways



Designing for Learner Needs



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