EVIDENCE REVIEW

WILL TECHNOLOGY TRANSFORM EDUCATION FOR THE BETTER?

This publication summarizes a forthcoming academic review paper on education technology, "Upgrading Education with Technology: Insights from Experimental Research."

OVERVIEW AND POLICY ISSUES

In recent years, there has been widespread excitement around the transformative potential of technology in education. In the United States alone, spending on education technology has exceeded $13 billion.[1] Programs and policies to promote the use of education technology (or "ed tech")—including hardware distribution, educational software, text message campaigns, online courses, and more—may expand access to quality education, support students' learning in innovative ways, and help families navigate complex school systems. However, the rapid development of education technology in the United States is occurring in a context of deep and persistent inequality.[2] Depending on how programs are designed, how they are used, and who can access them, education technologies could alleviate or aggravate existing disparities.

While access to computers and internet is expanding, approximately five million school-age children still do not have a broadband internet connection at home,[3] putting them at a disadvantage for homework assignments, access to online resources, and digital literacy development. Low-income students and students of color in particular disproportionately lack access to technology.[4]

It is important to step back and understand how technology can help—or in some cases hinder—student learning. In this executive summary, we synthesize the experimental literature on technology-based education interventions, focusing on literature from developed countries.[5] We share key results and highlight areas for future inquiry.

1 Technology for Education Consortium. "How School Districts Can Save (Billions) on Edtech." Accessed December 20, 2018. https://marketbrief.edweek.org/wp-content/uploads/2017/03/How_School_Districts_Can_Save_Billions_on_Edtech.pdf.

2 Reardon, Sean, Demetra Kalogrides, and Kenneth Shores."The Geography of Racial/Ethnic Test Score Gaps." CEPA Working Paper No.16-10. Stanford Center for Education Policy Analysis, Stanford, CA, 2018.

3 Pew Research Center. "Digital divide persists even as lower-income Americans make gains in tech adoption." Accessed December 20, 2018. http://www.pewresearch.org/fact-tank/2017/03/22/digital-divide-persists-even-as-lower-income-americans-make-gains-in-tech-adoption/.

4 Bulman, George and Robert Fairlie. "Technology and Education." *Handbook of the Economics of Education* 5 (2015): 239-280.

5 This policy brief also references studies from developing countries when relevant.

KEY LESSONS

Initiatives that expand access to computers and internet alone generally do not improve kindergarten to 12th grade students' grades and test scores, but do increase computer usage and improve computer proficiency.

Educational software designed to help students develop particular skills at their own rate of progress have shown enormous promise in improving learning outcomes, particularly in math. There is some evidence to suggest that these programs can boost scores by the same amount as effective tutoring programs, yet more research is needed to fully understand the underlying mechanisms for why certain educational software programs are more effective than others.

Technology-based nudges that encourage specific, one-time actions—such as text message reminders to complete college course registrations—can have meaningful, if modest, impacts on a variety of education-related outcomes, often at low costs.

Technology-enabled social psychology interventions—such as growth mindset interventions—can have significant and meaningful effects relative to their low costs, but these effects tend to be small and effective only for specific groups of students.

Combining online and in-person instruction can work as well as traditional in-person only classes, which suggests blended learning may be a cost-effective approach for delivering instruction. Students in online-only courses, however, tend to perform worse than students in in-person-only courses.

Many novel applications of technology to education, such as the use of interactive whiteboards or virtual reality, attract wide interest from school administrators but have not yet been rigorously evaluated for their efficacy. More research is needed to help identify which products boost student learning and reduce, rather than widen, existing inequalities in education.

METHODOLOGY

We share evidence from 126 randomized evaluations and regression discontinuity designs, grouped together as experimental evidence in this publication. We included papers if they were high-quality evaluations conducted in a developed country and tested interventions that utilized some form of technology to improve learning-related outcomes. Randomized evaluations from developing countries are not formally included in this review, although they are mentioned when relevant to the broader discussion of how technology impacts learning.

RIGOROUS METHODOLOGIES TO ESTIMATE CAUSAL IMPACT

Randomized evaluations—when properly implemented—are generally considered the strongest research design for quantitatively estimating average causal effects. Our review also chose to include regression discontinuity studies with large samples and well-defined thresholds because they produce estimated program effects identical to randomized evaluations for participants at a particular cutoff.[6]

MEASURING IMPACT

Comparing results across different studies can be difficult, especially when studies conducted in different contexts measure different outcomes—or even use different tests to look at the same outcome. While these differences can never be completely eliminated, we can contextualize results using a roughly comparable unit called a standard deviation. Standard deviations can give us a sense of the general size of impact across contexts (see table 1).

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TABLE 1. STANDARD DEVIATIONS

EFFECT SIZE	INTERPRETATION[7]
0.10 standard deviations	50th percentile to 54th percentile
0.20 standard deviations	50th percentile to 58th percentile
0.30 standard deviations	50th percentile to 62nd percentile
0.40 standard deviations	50th percentile to 66th percentile

[6] Regression discontinuity designs (RDDs) are quasi-experiments that identify a well-defined cutoff threshold. The cutoff threshold defines a change in eligibility or program status for those above it—for instance, the minimum test score required for a student to be eligible for financial aid. It may be plausible to think that treatment status is 'as good as randomly assigned' among the subsample of observations that fall just above and just below the threshold. The jump in an outcome between those just above and those just below the threshold can be interpreted as the causal effect of the intervention in question for those near the threshold. Berk et al. 2010; Cook and Wong 2008; Shadish et al. 2011.

[7] This chart says that an intervention with effect size of 0.10 standard deviations moves a student who scored at the 50th percentile up to the 54th percentile, for example. This interpretation assumes a normal distribution.

RESULTS

I. Supplying computers and internet alone generally do not improve students' academic outcomes, but do increase computer usage and improve computer proficiency.

Disparities in access to information and communication technologies can exacerbate existing educational inequalities. Students without access at school or at home may struggle to complete web-based assignments and may have a hard time developing digital literacy skills. Ever since technology's incorporation in the classroom took off during the 1990s, governments and other stakeholders have invested heavily in technology distribution and subsidy initiatives to expand access.[8] At the same time, increasing access to technology may have adverse impacts on academic achievement, for example if students end up using technology only for recreational purposes.

When it comes to academic achievement, computer distribution and internet subsidy programs generally did not improve grades and test scores at the K-12 level. In the United States, the Netherlands, and Romania, distributing free computers to primary and secondary students did not improve—and sometimes harmed—test scores.[9] In studies that found negative results, researchers find suggestive evidence that family rules regarding computer use and homework appear to mitigate some of the negative effects.[10]

Experimental studies conducted in developing countries have, for the most part, come up with similar results.[11] However, one program in China that combined computer distribution with educational software boosted test scores, suggesting distributing hardware while sharing specific learning tools may be a promising approach.[12]

At the postsecondary level, computer distribution programs appear to be more promising, although evidence comes mainly from one randomized evaluation at a community college. Distributing laptops to low-income students at a northern California community college had modest but positive effects on passing rates, graduation rates, and likelihood of taking a transfer course for a four-year college, at least in part because it saved time previously spent accessing computer labs.[13]

Laptop distribution also increased computer skills. Computer skills rose more meaningfully for minorities, women, lower-income, and younger students.[14] More research is needed to determine whether these results would successfully replicate to other contexts.

Broadly, programs to expand access to technology have been effective at increasing use of computers and improving computer skills.[15] Though perhaps intuitive, this is noteworthy given the logistical challenges of technology distribution, the potential reluctance of students and educators to adopt technology into daily practice, and the increasing importance of digital literacy skills.

Evidence base: 13 experimental papers

II. Educational software (or "computer-assisted learning") programs designed to help students develop particular skills have shown enormous promise in improving learning outcomes, particularly in math.

Targeting instruction to meet students' learning levels has been found to be effective in improving student learning, but large class sizes with a wide range of learning levels can make it hard for teachers to personalize instruction.[16] Software has the potential to overcome traditional classroom constraints by customizing activities for each student. Educational software–or "computer-assisted learning"–programs range from light-touch homework support tools to more intensive interventions that re-orient the classroom around the use of software. Most educational software that have been evaluated experimentally help students practice particular skills through "personalized tutoring" approaches.[17]

Computer-assisted learning programs have shown enormous promise in improving academic achievement, especially in math. Of all thirty studies of computer-assisted learning programs, twenty reported statistically significant positive effects.[18] Fifteen of the twenty programs found to be effective

[8] White House Office of the Press Secretary. "President Obama Announces ConnectALL Initiative." Accessed December 21, 2018. https://obamawhitehouse.archives.gov/the-press-office/2016/03/09/fact-sheet-president-obama-announces-connectall-initiative.

[9] Fairlie and Robinson 2013; Leuven et al. 2007; Malamud and Pop-Eleches 2011.

[10] Malamud and Pop-Eleches 2011.

[11] Beuermann et al. 2015; Cristia et al. 2012; Piper et al. 2016.

[12] Mo et al. 2015.

[13] Fairlie and London 2012.

[14] Ibid.

[15] Fairlie and Robinson 2013.

[16] Banerjee et al. 2007; Banerjee et al. 2016.

[17] Kulik and Fletcher 2015.

[18] Barrow et al. 2009; Beal et al. 2013; Campuzano et al. 2009; Deault et al. 2009; Hegedus et al. 2015; Kelly et al. 2013; Mitchell and Fox 2001; Morgan and Ritter 2002; Pane et al. 2014; Ragosta 1982; Ritter et al. 2007; Roschelle et al. 2010; Roschelle et al. 2016; Schenke et al. 2014; Singh et al. 2011; Snipes et al. 2015; Tatar et al. 2008; Wang and Woodworth 2011; Wijekumar et al. 2012; and Wijekumar et al. 2014 report positive effects in at least one treatment arm. Borman et al. 2009; Cabalo et al. 2007; Cavalluzzo et al. 2012; Dynarski et al. 2007; Faber and Visscher 2018; Pane et al. 2010; Rouse and Krueger 2004; Rutherford et al. 2014; and Van Klaveren et al. 2017 do not report positive effects. Pane 2014 only finds positive impacts on math outcomes in the second year.

PHOTO: SHUTTERSTOCK.COM

were focused on improving math outcomes.[19] A study of a math program that enabled students to control the motions of animated characters by building or editing mathematical functions showed the largest effect sizes of any large-scale study included in the review—0.63 and 0.56 standard deviation improvements in math scores for seventh and eighth graders, respectively.[20] While other studies of computer-assisted math programs demonstrated more modest effects, they continued to show promise. A number of these programs adapted instruction to meet student needs by leveraging artificial intelligence and machine learning. Other effective programs provided timely feedback to students and shared data on student performance with teachers to inform their approach.

When it comes to computer-assisted reading programs, the evidence was limited and showed mixed results. A program that taught students a technique for breaking down texts boosted middle school reading comprehension scores by 0.2 to 0.53 standard deviations,[21] demonstrating that computer-assisted learning has the potential to support students in literacy development as well as in math.

COMPUTER-ASSISTED LEARNING

An evaluation of a supplementary math homework program in Maine boosted average scores by 0.18 standard deviations despite requiring less than thirty to forty minutes per week.[22] This program gives students feedback and guidance as they work through math problems and sends student data to teachers to help them meet students' needs. This program had a positive effect on student achievement, with a significantly larger effect size for students at or below the median.

Note that this program required access to a laptop or a tablet—programs that expand access to technology (described in section I) may sometimes be necessary to generate the positive effects associated with computer-assisted learning (described in section II).

Evidence base: 30 experimental papers

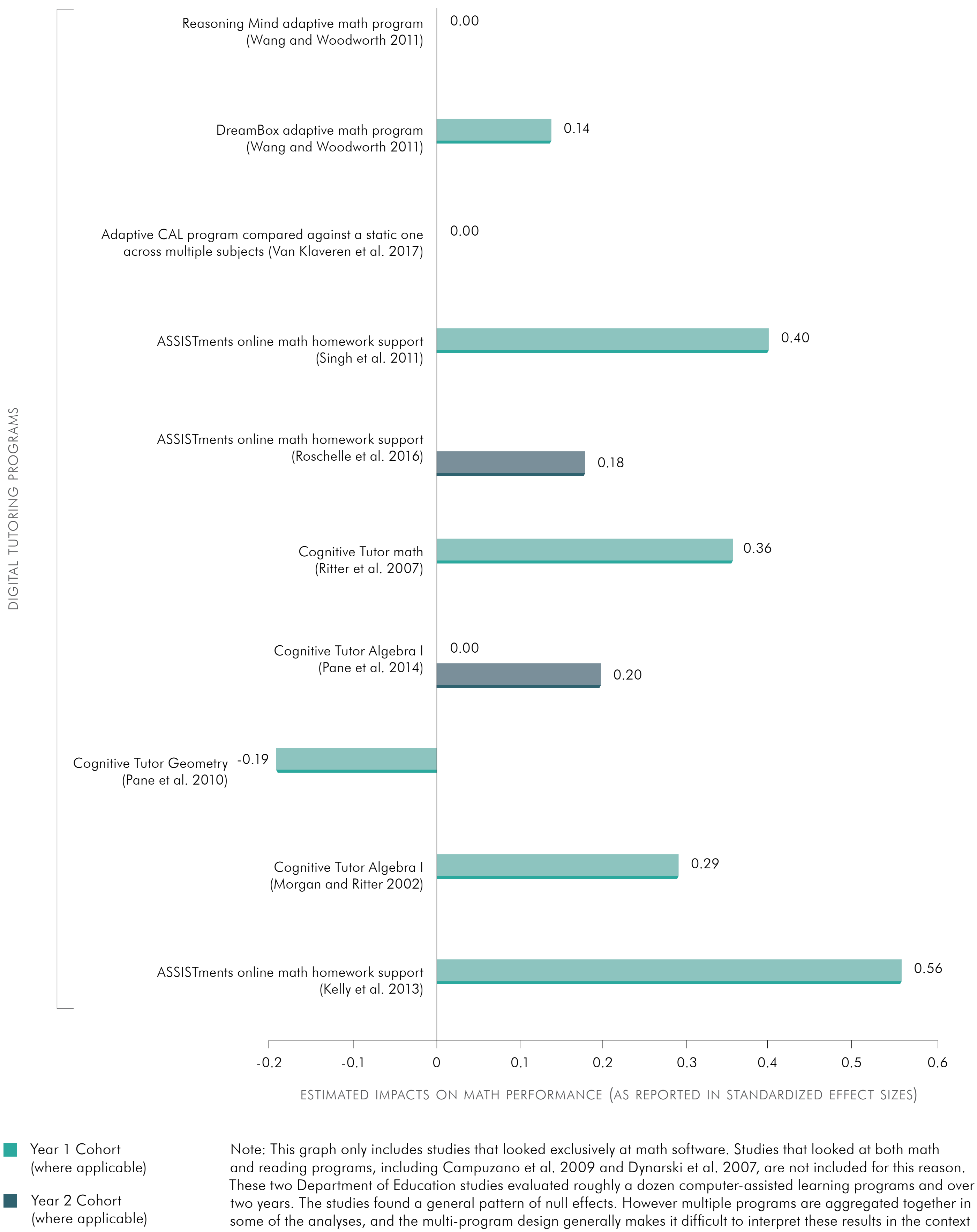
[19] Barrow et al. 2009; Beal et al. 2013; Hegedus et al. 2015; Kelly et al. 2013; Morgan and Ritter 2002; Pane et al. 2014; Ragosta 1982; Ritter et al. 2007; Roschelle et al. 2010; Roschelle et al. 2016; Schenke et al. 2014; Singh et al. 2011; Snipes et al. 2015; Tatar et al. 2008; Wang and Woodworth 2011. Pane 2014 only finds positive impacts on math outcomes in the second year. Campuzano et al. 2009 did not focus exclusively on math outcomes and is therefore not included in this count.

[20] Roschelle et al. 2010.

[21] Wijekumar et al. 2012; Wijekumar et al. 2014.

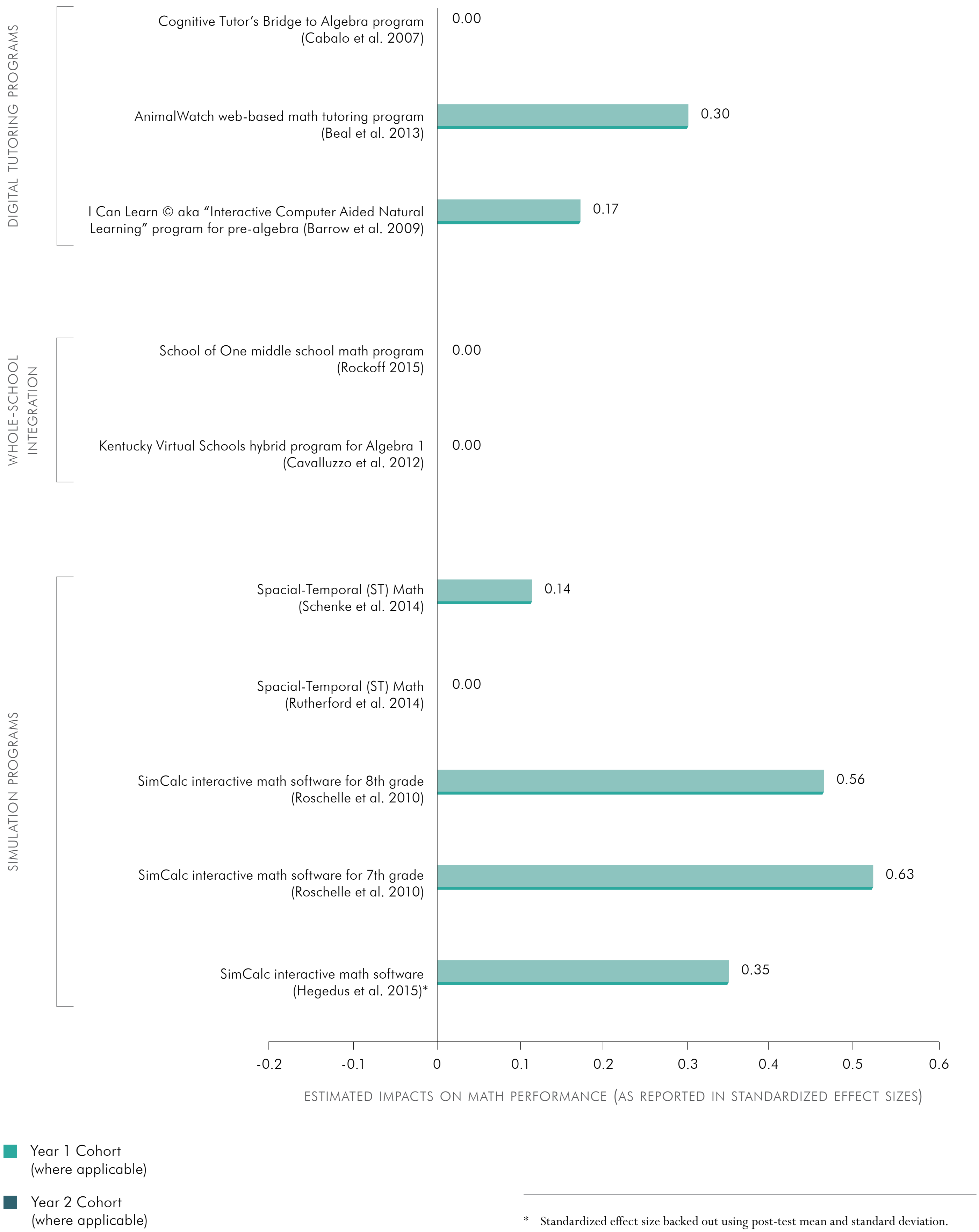
[22] Roschelle et al. 2016.

FIGURE 1. COMPUTER-ASSISTED LEARNING: IMPACT ON STUDENT LEARNING IN MATH



Note: This graph only includes studies that looked exclusively at math software. Studies that looked at both math and reading programs, including Campuzano et al. 2009 and Dynarski et al. 2007, are not included for this reason. These two Department of Education studies evaluated roughly a dozen computer-assisted learning programs and over two years. The studies found a general pattern of null effects. However multiple programs are aggregated together in some of the analyses, and the multi-program design generally makes it difficult to interpret these results in the context of the other studies discussed here.

FIGURE 1. COMPUTER-ASSISTED LEARNING: IMPACT ON STUDENT LEARNING IN MATH *(CONTINUED)*



* Standardized effect size backed out using post-test mean and standard deviation.


PHOTO: SHUTTERSTOCK.COM

III. Technology-based nudges—such as text message reminders—can have meaningful, if modest, impacts on a variety of education-related outcomes, often at extremely low costs.

Technology can be used to help address systematic biases in decision-making and other psychological factors that lead to unintended outcomes, like high school graduates not enrolling in college as a result of missing financial aid deadlines. Low-cost interventions like text message reminders can successfully support students and families at each stage of schooling.

Early Childhood and Elementary: Programs to Increase Literacy and Learning at Home (7 experimental papers)

Young children do better in school if their parents have encouraged and participated in learning activities at home.[23] However, parents—especially low-income parents dealing with high stress, limited resources, and time constraints at home—do not always regularly dedicate time to these activities.

Text messages with reminders, tips, goal-setting tools, and encouragement can increase parental engagement in learning activities, such as reading with their children. For example, a preschool program in San Francisco that texted suggestions to parents of small, easy tasks, provided encouragement, and sent reminders increased parental engagement and boosted children's literacy scores (with effect sizes ranging from 0.21 to 0.34 standard deviations).[24] While a similar standardized program in San Francisco kindergartens showed no impact, texts to parents with specific recommendations matched to each kindergartener's reading level showed substantial benefits.[25]

Middle and High School: Programs to Facilitate School-Parent Communication (13 experimental papers)

In middle and high schools in the U.S., the role of parents typically shifts away from direct activities with children and toward encouraging teenagers' effort in school. Schools can help parents support their children by providing families with information about their children's performance.

Technology can make this communication easier, faster, and more systematic. Programs to facilitate school-parent communication—including sending grades and attendance information and sharing personalized feedback—have shown promising results. Eight of ten studies focused on improving school-family information flows demonstrated positive effects on student GPAs, test scores, assignment scores, and/or attendance.[26]

MESSAGING MATTERS IN SCHOOL-FAMILY COMMUNICATION

Keep your school community in mind when selecting and designing programs.

- Identify barriers to student engagement to assess whether this approach makes sense in your context.
- Choose communication methods that parents can access easily, and select opt-out rather than opt-in programs where possible.
- Use language and translation options in schools with parents who are English Language Learners.

Personalized feedback and specific action items can increase student engagement.

Think carefully about the tone and messaging to parents as family-school communication can affect student-teacher relationships.

[23] Levine, Susan C., Linda Suriyakham, Meredith Rowe, Jenellen Huttenlocher, & Elizabeth Gunderson. 2010. "What Counts in the Development of Young Children's Number Knowledge?" *Developmental Psychology* 46: 1309-1319; Price 2010; Sénéchal and LeFevre 2002.

[24] York and Loeb 2018.

[25] Doss et al. 2018.

[26] Bergman 2015; Bergman 2016; Bergman and Chan 2017; Bergman et al. 2018; Bergman and Rogers 2016; Kraft and Dougherty 2013; Kraft and Rogers 2015; and Rogers and Feller 2016 found positive effects. Balu et al. 2016 and Bergman and Hill 2018 did not find positive effects.

Transitioning to College: Programs to Support the College Application Process, Financial Aid, and Enrollment (19 experimental papers)

As students near the end of high school, they have the opportunity to pursue further education. However, the college application process can be complex and overwhelming. Technology-based programs to personalize support and share reminders on specific tasks may help smooth this process.

While interventions that provided generic information on education tax credits or financial aid did not increase college enrollment in the U.S.,[27] programs that provided timely, specific, and personalized information were more consistently effective. In particular, programs that leveraged technology to suggest specific action items, streamline financial aid procedures, and/or provide personalized support boosted college application and enrollment rates[28] and encouraged better-informed financial aid decisions.[29] For example, personalized text messages increased college matriculation by 3.3 percentage points among students who had been accepted to and planned to attend Georgia State University.[30] This program sent reminders based on specific incomplete required tasks and leveraged artificial intelligence to automate responses to common student questions. Programs like this one can reduce the proportion of students who register for college but then do not show up. Programs that combined technology with in-person supports also improved financial aid receipt, college matriculation, and college persistence.[31]

Social Psychology Interventions: Programs to Develop Resilience, Confidence, and Positive Learning Attitudes (15 experimental papers)

Students' educational performance can be heavily affected by emotions, beliefs, and attitudes. Technology-enabled social psychology interventions aim to alleviate psychological barriers and cultivate confidence and positive learning attitudes. A common social psychology intervention, for example, is to reinforce the idea that intelligence is not fixed and rather can grow through hard work.[32]

Despite promising evidence from small-scale studies, large-scale studies have found that technology-enabled social psychology interventions do not improve academic outcomes on average, although they can lead to meaningful effects under some circumstances.[33] These effects tend to be concentrated within subsamples and, even then, tend to be quite small.[34] In some cases where social psychology interventions did not improve academic outcomes, they did have a positive impact on psychological outcomes, for example, the likelihood of taking academic risks.[35] Findings from studies so far have generated hints that certain students may benefit more from social psychology interventions. For instance, those who start out further behind in terms of academic performance and/or social-psychological attitudes tend to respond better to social psychology interventions. However, the current evidence is far from sufficient to state this conclusively.

Evidence base: 54 experimental papers

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[27] Bergman et al. 2016; Darolia 2016; Hyman 2018; Page et al. 2016. Note that the evidence from outside the United States shows that information interventions can lead to positive effects on related outcomes, including views of higher education and knowledge of financial aid. See Oreopoulos and Dunn 2013 and Dinkelman and Martinez 2014.

[28] Castleman and Page 2015; Castleman and Page 2016. Oreopoulos and Petronijevic 2017 found text-based advising was not effective for first year college students in Canada.

[29] Barr et al. 2016; Bird et al. 2017; Castleman and Page 2015; Castleman and Page 2016.

[30] Page and Gehlbach 2017.

[31] Bettinger et al. 2012; Castleman et al. 2012; Castleman and Meyer 2016; Oreopoulos and Ford 2016.

[32] Snipes et al. 2012.

[33] Pauneksu et al. 2015; Yeager et al. 2016.

[34] Ibid.

[35] Unkovic et al. 2016; Forsyth et al. 2007.

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IV. Online courses are developing a growing presence in education, but the limited experimental evidence suggests that online courses lower student academic achievement compared to in-person courses. However, students perform similarly in courses with both in-person and online components compared to traditional face-to-face classes. In Massive Open Online Courses (MOOCs), behavioral interventions (like the mindset interventions described in section III) increased course persistence and completion rates.

Since their emergence in the 1990s, online courses have developed a growing presence in education. Proponents of conventional online courses and massive open online courses (MOOCs) highlight their potential to reduce costs and improve access. Post-secondary students who enroll in conventional online programs tend to be more likely to face educational disadvantages compared to students in traditional programs.[36]

Conventional Online Courses (17 experimental studies)

Conventional online courses—taught as part of entirely online degree programs or degree programs that include online or partially online courses—have grown in popularity in the last decade. However, in four of six studies[37] that directly compared the impact of taking a course online versus in-person only, found that student performance was lower in online courses. It is possible that students taking online courses may struggle with the lack of accountability or miss out on motivating relationships with instructors and peers. Nonetheless, students generally performed similarly—and in some cases better—in courses that included both a face-to-face component and an online component and in courses that were entirely face-to-face.[38]

One study did find that offering 8th grade students the option to enroll in an online algebra course in schools where a standalone algebra class was not offered improved algebra achievement and also increased the likelihood of participation in an advanced math course sequence in high school.[39] However, it is possible that students would have learned even more had they taken an in-person algebra course rather than an online course.

One study assessed whether online programs expand access to students who would not otherwise enroll in a degree programs, finding that Georgia Tech's online master's program in computer science did expand access, especially among mid-career prospective students.[40]

36 Deming et al. 2015.

37 Alpert et al. 2016; Figlio 2013; Heppen et al. 2012; Keefe 2003; Poirier and Feldman 2004; Zhang 2005.

38 Alpert et al. 2016; Bowen et al. 2014; Esperanza et al. 2016; Foldnes 2016; Harrington et al. 2015; Joyce et al. 2015. Wozny et al. 2018. Positive effects from blended learning were found only in three of the four studies that specifically tested the flipped classroom model, which reverses traditional instruction by delivering content that is typically taught in the classroom at home via the internet (Esperanza et al. 2016; Foldnes 2016; Wozny et al. 2018.)

39 Heppen et al. 2011.

40 Goodman et al. 2016.

PHOTO: SHUTTERSTOCK.COM

Massive Open Online Courses (MOOCs) (11 experimental studies)

Offering open access and unlimited participation, MOOCs have the potential to reach many more students in a more diverse range of contexts than conventional online courses. Millions of students are enrolled in MOOCs worldwide.[41] MOOCs have the potential to provide access to high-quality coursework to students with fewer educational opportunities, but enrollment and success rates are highly skewed toward populations with more financial resources.[42] Broadly speaking, MOOCs face very low completion rates.[43]

Experimental research on MOOCs has focused primarily on whether and how behavioral interventions can improve MOOC completion rates and extend coverage to students with limited educational opportunities. Interventions to increase completion rates through mindset interventions (like those discussed in section III) have typically increased persistence. Seven of the nine studies evaluating these types of interventions found positive effects from at least one treatment arm.[44] For example, information on performance relative to peers,[45] commitment devices to limit distractions,[46] planning prompts,[47] and writing exercises aimed at increasing a sense of belonging[48] boosted completion rates.

Evidence base: 28 experimental papers

[41] Shah 2018. Accessed January 11, 2019. https://www.edsurge.com/news/2018-01-22-a-product-at-every-price-a-review-of-mooc-stats-and-trends-in-2017.

[42] Hansen and Reich 2015.

[43] Banerjee and Duflo 2014.

[44] Banerjee and Duflo 2016; Davis et al. 2017; Kizilcec et al. 2014; Kizilcec et al. 2017; Lamb et al. 2015; Martinez 2014A; Martinez 2014B; Patterson 2015; Yeomans and Reich 2017. Banerjee and Duflo 2016 and Kizilcec et al. 2014 do not find positive effects.

[45] Davis et al. 2017; Martinez 2014A.

[46] Patterson 2015.

[47] Yeomans and Reich 2017.

[48] Kizilcec et al. 2017.

INTERVENTION TYPE	RESEARCHERS	PROGRAM DETAILS
Access to Technology	Carter et al. (2016)	Prohibiting use of computers during a college economics class
Access to Technology	Faber et al. (2015)	Differences in broadband connection speeds
Access to Technology	Fairlie (2012A)	One-to-one laptop distribution
Access to Technology	Fairlie (2012B)	One-to-one laptop distribution
Access to Technology	Fairlie (2015)	One-to-one laptop distribution
Access to Technology	Fairlie and Bahr (2018)	One-to-one laptop distribution
Access to Technology	Fairlie and Grunberg (2014)	One-to-one laptop distribution
Access to Technology	Fairlie and Kalil (2017)	One-to-one laptop distribution
Access to Technology	Fairlie and London (2012)	One-to-one laptop distribution
Access to Technology	Fairlie and Robinson (2013)	One-to-one laptop distribution
Access to Technology	Goolsbee and Guryan (2006)	E-Rate, subsidy for internet in schools
Access to Technology	Leuven et al. (2007)	Subsidies for computers and software in under-resourced schools
Access to Technology	Malamud and Pop-Eleches (2011)	Euro 200 program, subsidy for low-income families with schoolchildren to buy computers
Computer-Assisted Learning	Barrow et al. (2009)	I Can Learn© aka "Interactive Computer Aided Natural Learning" program for pre-algebra and algebra
Computer-Assisted Learning	Beal et al. (2013)	AnimalWatch web-based math tutoring program
Computer-Assisted Learning	Borman et al. (2009)	Fast ForWord computer-based language and reading training program
Computer-Assisted Learning	Cabalo et al. (2007)	Cognitive Tutor's Bridge to Algebra program
Computer-Assisted Learning	Campuzano et al. (2009)	16 types of software products for math and reading
Computer-Assisted Learning	Cavalluzzo et al. (2012)	Kentucky Virtual Schools hybrid program for Algebra 1
Computer-Assisted Learning	Dynarksi et al. (2007)	16 types of software products for math and reading
Computer-Assisted Learning	Deault et al. (2009)	ABRACADABRA web-based literacy program
Computer-Assisted Learning	Faber and Visccher (2018)	Snappet digital formative assessment tool focused on spelling
Computer-Assisted Learning	Hegedus et al. (2015)	SimCalc interactive math software

APPENDIX: EVALUATIONS INCLUDED IN THIS REVIEW

INTERVENTION TYPE	RESEARCHERS	PROGRAM DETAILS
Computer-Assisted Learning	Kelly et al. (2013)	ASSISTments online math homework support
Computer-Assisted Learning	Mitchell and Fox (2001)	DaisyQuest and Daisy's Castle reading game
Computer-Assisted Learning	Morgan and Ritter (2002)	Cognitive Tutor Algebra I
Computer-Assisted Learning	Pane et al. (2010)	Cognitive Tutor Geometry
Computer-Assisted Learning	Pane et al. (2014)	Cognitive Tutor Algebra I
Computer-Assisted Learning	Ragosta (1982)	Cognitive Tutor for math
Computer-Assisted Learning	Ritter et al. (2007)	Cognitive Tutor for math
Computer-Assisted Learning	Rockoff (2015)	School of One middle school math program
Computer-Assisted Learning	Roschelle et al. (2010)	SimCalc interactive math software
Computer-Assisted Learning	Roschelle et al. (2016)	ASSISTments online math homework support
Computer-Assisted Learning	Rouse and Krueger (2004)	Fast ForWord computer-based language and reading training program
Computer-Assisted Learning	Rutherford et al. (2014)	Spatial-Temporal (ST) Math
Computer-Assisted Learning	Schenke et al. (2014)	Spatial-Temporal (ST) Math
Computer-Assisted Learning	Singh et al. (2011)	ASSISTments online math homework support
Computer-Assisted Learning	Snipes et al. (2015)	Elevate summer math program
Computer-Assisted Learning	Tatar et al. (2008)	SimCalc interactive math software
Computer-Assisted Learning	Van Klaveren et al. (2017)	Adaptive CAL program compared against a static program across multiple subjects
Computer-Assisted Learning	Wang and Woodworth (2011)	(1) DreamBox math program; (2) Reasoning Mind math program
Computer-Assisted Learning	Wijekumar et al. (2012)	ITSS (Intelligent Tutoring for Structure Strategy) program for reading and language
Computer-Assisted Learning	Wijekumar et al. (2014)	ITSS (Intelligent Tutoring for Structure Strategy) program for reading and language
Behavioral Interventions (Early Childhood)	Cortes et al. (2018)	Text messaging program to nudge parents of kindergarteners to engage in literacy activities with children
Behavioral Interventions (Early Childhood)	Doss et al. (2018)	Text messaging program to nudge parents of kindergarteners to engage in literacy activities with children
Behavioral Interventions (Early Childhood)	Kraft and Monti-Nussbaum (2017)	Parents texted to encourage engagement in activities to counteract summer learning loss

APPENDIX: EVALUATIONS INCLUDED IN THIS REVIEW

INTERVENTION TYPE	RESEARCHERS	PROGRAM DETAILS
Behavioral Interventions (Early Childhood)	Kraft and Rogers (2015)	Parents texted on student behavior/performance
Behavioral Interventions (Early Childhood)	Mayer et al. (2015)	Texting program to promote learning engagement of Head Start parents
Behavioral Interventions (Early Childhood)	Meuwissen et al.	Text2Learn, a mobile phone texting program for low-income parents of preschoolers
Behavioral Interventions (Early Childhood)	York and Loeb (2018)	Text messaging program to nudge preschool parents to engage in literacy activities with children
Behavioral Interventions (Primary/Secondary)	Balu et al. (2016)	Automated text messages to parents of high school students informing about absence
Behavioral Interventions (Primary/Secondary)	Bergman (2015)	Automated texts to parents about performance
Behavioral Interventions (Primary/Secondary)	Bergman (2016)	Learning Management System (parents have access to an online portal with child's classes, grades, assignments, etc.)
Behavioral Interventions (Primary/Secondary)	Bergman and Chan (2017)	Automated texts to parents about performance
Behavioral Interventions (Primary/Secondary)	Bergman et al. (2018)	Providing regular information to families about their child's academic progress in one arm and supplementing with home visits on skills-based information in a separate arm
Behavioral Interventions (Primary/Secondary)	Bergman and Hill (2018)	Publishing teacher ratings online
Behavioral Interventions (Primary/Secondary)	Bergman and Rogers (2016)	Text message to parents regarding their child's academic performance, including grades, upcoming tests and missing assignments
Behavioral Interventions (Primary/Secondary)	Bursztyn and Jensen (2015)	Two interventions: (1) performance leaderboard into computer-based high school courses; (2) Complimentary access to an online SAT preparatory course. Sign-up forms differed randomly across students only in whether they said the decision would be kept private from classmates
Behavioral Interventions (Primary/Secondary)	Fryer (2016)	Provided free cellular phones and daily information about the link between human capital and future outcomes via text message in one treatment and minutes to talk and text as an incentive in a second treatment
Behavioral Interventions (Primary/Secondary)	Kraft and Dougherty (2013)	Parents texted about student behavior/performance
Behavioral Interventions (Primary/Secondary)	Kraft and Rogers (2015)	Parents texted about student behavior/performance

APPENDIX: EVALUATIONS INCLUDED IN THIS REVIEW

INTERVENTION TYPE	RESEARCHERS	PROGRAM DETAILS
Behavioral Interventions (Primary/Secondary)	McGuigan et al. (2012)	Information campaign about the costs and benefits of pursuing post compulsory education
Behavioral Interventions (Primary/Secondary)	Rogers and Feller (2016)	One of three personalized message information treatments throughout the school year
Behavioral Interventions (Post-secondary)	Barr et al. (2016)	Text messaging campaign prompting loan applicants at a large community college to make informed and active borrowing decisions
Behavioral Interventions (Post-secondary)	Bergman et al. (2016)	E-mails and letters to potential/prospective/current college students about financial aid/incentives
Behavioral Interventions (Post-secondary)	Bettinger et al. (2012)	FAFSA assistance during tax filing
Behavioral Interventions (Post-secondary)	Bird et al. (2017)	Nudges for early FAFSA filing through Common App
Behavioral Interventions (Post-secondary)	Castleman et al. (2012)	Providing college counseling to low income students during the summer through email, text message, and in-person consultation
Behavioral Interventions (Post-secondary)	Castleman and Meyer (2016)	A text messaging campaign to provide lower-income college students with simplified information, encouragement, and access to one-on-one advising
Behavioral Interventions (Post-secondary)	Castleman and Page (2015)	Text messages to reduce summer melt
Behavioral Interventions (Post-secondary)	Castleman and Page (2016A)	Text messages to improve FAFSA re-filing for sophomore year
Behavioral Interventions (Post-secondary)	Castleman and Page (2016B)	Text messages to improve enrollment tasks
Behavioral Interventions (Post-secondary)	Chande et al. (2015)	Texting motivational messages and organizational reminders to students
Behavioral Interventions (Post-secondary)	Darolia (2016)	Letters e-mailed to students regarding financial aid
Behavioral Interventions (Post-secondary)	Hyman (2018)	Mailing letters with web address to college information website
Behavioral Interventions (Post-secondary)	Ksoll et al. (2014)	Mobile phone-based adult education program (Cell-Ed)
Behavioral Interventions (Post-secondary)	O'Connell and Lang (2018)	Personalized email reminders encouraging out-of-class study
Behavioral Interventions (Post-secondary)	Oreopoulos and Dunn (2013)	3-minute video and opportunity to use financial aid calculator

APPENDIX: EVALUATIONS INCLUDED IN THIS REVIEW

INTERVENTION TYPE	RESEARCHERS	PROGRAM DETAILS
Behavioral Interventions (Post-secondary)	Oreopoulos and Ford (2016)	Application assistance with technology incorporated into the high school curriculum
Behavioral Interventions (Post-secondary)	Oreopoulos and Petronijevic (2017)	Text-based advising
Behavioral Interventions (Post-secondary)	Page et al. (2016)	FAFSA texting program
Behavioral Interventions (Post-secondary)	Page and Gehlbach (2017)	Text message reminders and assistance with matriculation requirements during the summer before freshman year for students who were accepted and plan to attend college
Behavioral Interventions (Post-secondary)	Smith et al. (2018)	Software that sends a "grade nudge," a personalized message to each homework assignment regarding the student's current grade
Behavioral Interventions (Social Psychology)	Forsyth et al. (2007)	Self-esteem bolstering intervention
Behavioral Interventions (Social Psychology)	Good et al. (2003)	E-mail mentorship by college students who encouraged middle school students to view intelligence as malleable or to attribute academic difficulties in the seventh grade to the novelty of the educational setting
Behavioral Interventions (Social Psychology)	Harackiewicz et al. (2012)	Three-part intervention (two brochures mailed to parents and a website) highlighting the usefulness of STEM courses
Behavioral Interventions (Social Psychology)	Morisano et al. (2010)	Goal-setting program
Behavioral Interventions (Social Psychology)	Paunesku et al. (2015)	Growth-mindset and sense-of-purpose interventions
Behavioral Interventions (Social Psychology)	Oreopoulos et al. (2018)	Choose-Your-Own-Challenge online modules designed to teach students effective learning behaviors and adaptive perspectives
Behavioral Interventions (Social Psychology)	Oreopoulos et al. (2018)	Online planning exercise with information and guidance to create a weekly schedule containing sufficient study time and other obligations
Behavioral Interventions (Social Psychology)	Unkovic et al. (2016)	Personalized emails encouraging graduate students to apply for a conference
Behavioral Interventions (Social Psychology)	Walton et al. (2015)	Social-belonging intervention to protect students' sense of self-belonging Affirmation-training intervention to help students manage stress related to social marginalization
Behavioral Interventions (Social Psychology)	Yeager et al. (2013)	6-session intervention that taught an incremental theory (a belief in the potential for personal change) through Cyberball electronic game

INTERVENTION TYPE	RESEARCHERS	PROGRAM DETAILS
Behavioral Interventions (Social Psychology)	Yeager et al. (2014)	A malleable (incremental) theory of personality—the belief that people can change
Behavioral Interventions (Social Psychology)	Yeager et al. (2014)	Promoting a prosocial, self-transcendent purpose
Behavioral Interventions (Social Psychology)	Yeager et al. (2016A)	Growth mindset interventions during the transition to high school: Qualitative inquiry and rapid, iterative, randomized "A/B" experiments were conducted to inform intervention revisions for this population
Behavioral Interventions (Social Psychology)	Yeager et al. (2016B)	"Lay theory" intervention that explains the meaning of commonplace difficulties before college matriculation
Behavioral Interventions (Social Psychology)	Yeager et al. (2017)	A program teaching a growth mindset of intelligence
Online Learning	Alpert et al. (2016)	Face-to-face versus blended versus purely online course content
Online Learning	Bowen et al. (2014)	Blended instruction versus face-to-face only
Online Learning	Deming et al. (2016)	Resume audit of fictitious resumes varied by for-profit vs. public, online vs. brick-and-mortar
Online Learning	Esperanza et al. (2016)	Flipped classroom model
Online Learning	Figlio (2013)	Online lectures
Online Learning	Foldnes et al. (2016)	Flipped classroom model
Online Learning	Goodman et al. (2016)	Online Master of Science in Computer Science
Online Learning	Harrington et al. (2015)	Flipped classroom model
Online Learning	Joyce et al. (2015)	One class/week (blended) versus two classes/week (face-to-face)
Online Learning	Heppen et al. (2011)	Online Algebra I course
Online Learning	Heppen et al. (2012)	Online algebra courses for credit recovery
Online Learning	Keefe (2003)	Two studies: (1) lecture and interaction online versus traditional face-to-face; (2) interaction versus regular lecture experience
Online Learning	Jackson and Makarin (2018)	Teacher access to online off-the-shelf quality lessons and support to promote their use
Online Learning	Poirier and Feldman (2004)	Traditional face-to-face versus online course
Online Learning	Wozny et al. (2018	Flipped classroom model
Online Learning	Zhang (2005)	The interactive e-classroom component of the Learning By Asking system versus traditional face-to-face classrooms

APPENDIX: EVALUATIONS INCLUDED IN THIS REVIEW

INTERVENTION TYPE	RESEARCHERS	PROGRAM DETAILS
Online Learning	Zhang et al. (2006)	Interactive video, non-interactive video and without video learning environments
Massive Open Online Courses	Banerjee and Duflo (2014)	MOOC sign-up deadline
Massive Open Online Courses	Banerjee and Duflo (2016)	(1) Option to commit to structured study time; (2) Self-efficacy messages; (3) Tutoring services in groups of 20
Massive Open Online Courses	Davis et al. (2017)	A personalized feedback system that facilitates social comparison of current students with previously successful learners
Massive Open Online Courses	Davis et al. (2018)	MOOC-based Adaptive Retrieval Practice System, which delivers quiz questions from prior course units
Massive Open Online Courses	Kizilcec et al. (2014)	"Collectivist," "individualist," or "neutral" emails sent to MOOC participants to encourage forum participation
Massive Open Online Courses	Kizilcec et al. (2017)	Mindset interventions addressing social identity threat using a "value relevance affirmation" exercise and a "social-belonging intervention"
Massive Open Online Courses	Lamb et al. (2015)	Self-assessment questions aimed at improving forum participation for MOOC students: (1) a self-participation check; (2) discussion priming; and (3) discussion preview emails
Massive Open Online Courses	Martinez (2014A)	Emails informing students of their relative position in the course: (1) a "positive" one telling how many students recipients did better than; and (2) a "negative" one stating how other students outperformed the recipient
Massive Open Online Courses	Martinez (2014B)	E-mails on the negative correlation between procrastination and achievement
Massive Open Online Courses	Patterson (2015)	(1) A commitment device where students pre-commit to time limits on distracting Internet activities; (2) a reminder tool by time spent on distracting websites; (3) a focusing tool that allows students to block distracting sites on the course website
Massive Open Online Courses	Yeomans and Reich (2017)	Open-ended planning prompts asking students to describe any specific plans they made to engage with course content and complete assignments on time

CONCLUSIONS

Amidst the excitement and sizeable investment in education technology, we aim to step back and take stock of what we currently know from the experimental evidence:

Simply providing students with access to computer technology yielded largely mixed results. At the K-12 level, giving a child a computer may have limited impacts on learning outcomes, but generally improves computer proficiency and other cognitive outcomes. Distributing computers may have a more direct impact on learning outcomes at the postsecondary level.

Computer-assisted learning shows considerable promise. Potentially due to its ability to personalize instruction, computer-assisted learning can be quite effective in helping students learn, particularly with math. More research is needed to understand which components of computer-assisted learning most contribute to effective programs, how best to offer them, and which types of learning activities are best suited for software-based instruction.

Evaluations of technology-enabled behavioral interventions also generally find positive effects across all stages of schooling, although the impacts are generally small. Yet given their low cost, behavioral interventions like large-scale text message campaigns may be a cost-effective way to support students, families, and schools.

While technology-enabled social psychology interventions can have significant effects, impacts are generally small and specific to certain groups of students.

Though online learning courses have exploded in popularity over the last decade, **we found that relative to courses with some degree of face-to-face teaching, students taking online-only courses may experience negative learning outcomes.**

Going forward, we encourage additional research to further explore the potential role of education technology in schools, identify interventions that expand opportunity, and evaluate how underlying mechanisms can advance learning.

AREAS FOR FUTURE RESEARCH

These results highlight technology's potential to improve learning, especially when used to overcome existing constraints in instruction and learning. Though more research is needed before recommending broad-scale adoption, computer-assisted learning and technology-enabled behavioral interventions emerge as two particularly promising areas. Moving forward, a key goal will be to understand how these technologies can bridge gaps in educational access and reduce, rather than widen, disparities in learning. Building off what we now know, researchers and education practitioners have a major opportunity to study critical open questions about the impact of technology in education:

- In what ways does education technology reduce—or widen—disparities in education?
- What are the impacts of education technology on different types of learners?
- What types of learning activities can be effectively delivered through education technology?
- Which components of effective education technology programs are most important for student learning?
- What are the long-term impacts of education technology on student achievement?
- What are the replicability and scalability of programs that have been found to be effective?
- How should teachers and classrooms interact with education technology?
- What is the cost-effectiveness of technology-driven programs relative to other effective approaches in education?

Technology is developing at an astonishing pace—rapid advances in artificial intelligence and machine learning have already reshaped many aspects of daily life. Against this backdrop, promising uses of education technology have the potential to support massive inroads in learning. Yet, far more research is necessary to help determine which of these myriad education technologies are worth pursuing.

ABOUT J-PAL

The Abdul Latif Jameel Poverty Action Lab (J-PAL) is a global research center working to reduce poverty by ensuring that policy is informed by scientific evidence. Anchored by a network of 171 affiliated professors at universities around the world, J-PAL conducts randomized impact evaluations to answer critical questions in the fight against poverty.

FOR FURTHER READING

This evidence review is an executive summary of work by Maya Escueta, Andre Nickow, Phil Oreopoulos, and Vincent Quan:

"Upgrading Education with Technology: Insights from Experimental Research" (forthcoming)

"Education Technology: An Evidence-Based Review"

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