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Distance Learning

What Have We Learned?

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Executive Summary

Distance learning (or EdTech) interventions can increase the amount and quality of instruction students receive. Distance learning includes any instruction where content is not delivered by a live, in-person instructor, but instead by, or with, information communication technology (ICT), often because the instructor and student are not co-located. Sometimes the instructor and student are co-located, but the content is being delivered through technology directly, where the instructor is more of a facilitator than a traditional teacher. Distance learning interventions usually involve digital and audio-visual elements and can deliver instruction through lectures, demonstrations, animations, and simple SMS text, or provide interactive methods of learning, such as quizzes, puzzles, and games.

This review examines the empirical evidence to understand what drives the success (or failure) of distance learning interventions. The extent and urgency of access to education, and the global focus on the topic due to CoVID-19, call for more and better evidence-based action. The focus of the review is on the application of distance learning interventions and their impact on academic outcomes.

Distance learning interventions can either supplement or substitute for in-person learning – supplemental programs increase instructional time; substitute programs deliver better or more appropriate content. Our review reveals three findings:

Programs that increase the total amount of time students spend learning through additional instruction or homework tend to improve learning outcomes regardless of technology and design.

Distance learning interventions that displace status quo instruction will only have a positive impact if they deliver more accurate or appropriate content using a pedagogy that is more engaging, personalized, adaptive and/or interactive relative to the status quo.

For distance learning interventions to work, they must be implemented well, which may require reliable infrastructure, sufficient teacher training if teachers operate the ICT, and if students interact directly with the ICT, supervision or nudges to complete the work.

To tackle the more general problem of choosing, designing, and implementing distance learning interventions we recommend that policymakers follow three steps:

- Identify the specific education challenges (e.g., insufficient quantity of instruction due to access, quality of content and pedagogy due to insufficient teacher training) and understand how technology can address those challenges, given contextual constraints (e.g., ICT infrastructure, device penetration).

- Design the distance learning intervention, including choosing the right technology, considering contextual constraints, to address the problem identified in Step 1 and determining complementary program features such as facilitation or "flipping" classrooms.

- Pilot the intervention to understand its feasibility and efficacy. Evaluate its effectiveness at a larger scale. And once at scale, monitor the intervention to ensure implementation fidelity.

Introduction

Globally, many learners fall behind as education systems struggle with low quality and widespread inaccessibility. Despite the success of reducing the proportion of out-of-school children to less than ten percent (UNESCO), still, over 200 million school-aged children are not enrolled in school (World Bank 2018), 59 million of which are of primary school age (UNICEF 2019). Particularly relevant is the recent global CoVID-19 pandemic, which, at its peak, led most of the world's schools to close and placed approximately 1.3 billion children out of school worldwide (UNESCO 2020). Governments and policymakers are concerned that many of these students will not reenroll once schools reopen, with early evidence suggesting millions of new dropouts. [CGD blog] Quality education is also in short supply. Even with over 90% of students enrolled (UNESCO), an estimated 53% of children in low and middle-income countries cannot read proficiently by age ten (World Bank 2019).

Distance learning interventions or programs (we use the terms interchangeably) can provide new models of learning to address the challenges of both education access and quality. First, distance learning interventions can reach learners who face barriers attending traditional schooling due to distance, terrain, disability, discrimination, scheduling, as well as disasters and emergencies. Access is also not binary (zero schooling versus complete schooling). Barriers to schooling may be manifested through poor attendance of students or teachers, too few school days per year, or too few school hours per day. If students do not receive enough schooling to reach adequate learning outcomes, distance learning can act as a supplement.

Second, when the status-quo quality is poor due to limited resources at the school, educators can improve the quality of instruction by integrating distance learning tools that leverage technologies learners have at home (e.g., radio and phones). Around 70% of households in developing countries have access to a radio (UNESCO), 80% of the global population have access to a television (Butts 2013), 50% have access to a laptop or computer (Statista), 65% have access to a phone (Pew Research), and almost 50% have access to a smartphone (Statista). Therefore, for at least a large proportion of the population, the infrastructural prerequisites are in place to deliver distance learning.

There is a large body of evidence on individual distance learning interventions, the challenges they address, and their impacts. There are also several reviews of these interventions which categorize distance learning into different technologies and assess the relative success of each technology (USAID 2020; Education Endowment Foundation 2020). An evidence review from the Abdul Latif Jameel Poverty Action Lab (J-PAL) gives overviews on different dimensions of EdTech interventions: access to technology, computer-assisted learning, behavioral interventions, and online-learning (J-PAL 2019). Rodriguez-Segura (2020) uses a very similar framework to synthesize studies of EdTech interventions in developing countries. Ganimian, Vegas and Hess (2020) discuss how educational technology can be used to improve learning.

This review brings the different contributions of existing reviews into a single source, synthesizing evidence on the impact of different distance learning interventions, which features the programs have, and why or why not programs succeed in different contexts. The purpose of this review is to help policymakers and practitioners make decisions on what measures can be implemented to better address issues of educational access and quality.

1.1 Distance Learning Products, Programs and Features

Distance learning is commonly understood as instruction designed for out-of-school learning. More formally, and perhaps more broadly, it includes any instruction where content is not delivered by a live, in-person instructor, but instead by, or with, information communication technology (ICT), often because the instructor and student are not co-located. In this broader definition, students can be out of school or physically present in the school building while the "instructor" is not a physically present teacher.

In practice, distance learning can refer to any intervention that leverages ICT (hereafter, "technologies") to deliver content. These interventions usually include digital and audio-visual elements and can provide primary instruction, like lectures, demonstrations, animations, and simple SMS text, or provide interactive methods of learning, such as quizzes, puzzles, and games. Paper-based interventions such as homework, worksheets or a textbook to read at home, could fall under the umbrella of distance learning, however they are excluded in this review.

This review examines distance learning interventions and their impact on learning as outlined in the literature. The focus of the review is on the application of distance learning interventions in an academic setting, where status quo would be classroom-based instruction. Therefore, interventions applied to non-academic settings such as on the job training programs are excluded. Further, academic interventions that complement lab or field-based work are excluded too.

Distance learning incorporates EdTech, and therefore within this distance learning review there is also an EdTech review. This review also considers interventions that rely on radio and TV, which are typically not included in EdTech reviews.

Distance learning technologies typically fall into one or more of the following categories:

Audio: Audio-based learning is typically provided as structured Interactive Audio Instruction (IAI) or through educational entertainment programming ("edutainment"). The former mimics in-person instruction through promoting active learning while the latter integrates educational messaging within 'narrative' programming. Programs can be pre-recorded or broadcast live. Most audio instruction has been delivered through radio broadcasts or audio files on physical media (cassettes, DVDs, USBs), but, in recent years, programming has been delivered through the internet and cellular networks (mobile phones), such as robocalls or Interactive Voice Response (IVR).

Video: Like audio, video-based learning can be provided as structured Interactive Video Instruction (IVI) or through edutainment. Programs can be pre-recorded or broadcasted live via analogue, satellite, or digital television and include narrative-driven edutainment and traditional classroom-based instruction. Like IAI, interactivity in IVI and edutainment is typically facilitated with pauses for students to react or conduct assigned activities. In recent years, technologies have evolved to encompass interactive broadcast (via satellite or Internet). Video can also include simple (non-interactive) pre-recorded lectures delivered through broadcast, physical media, or the internet and played on televisions, projectors, computers, tablets and smartphones.

Text: Text-based Interventions (such as SMS or more recently, "chat-bots") are primarily delivered through mobile phones, leveraging high penetration rates of phones. Text interventions are typically not used as the primary method to deliver content; instead they are used to augment the delivery of traditional instruction or to complement other distance learning models. They can provide "behavioral nudges" encouraging participation, directly connect teachers to students outside of the classroom, or provide quiz-like problems or nudges to practice concepts delivered elsewhere.

E-learning: E-learning is usually dependent on "computer" hardware (including tablets, smartphones, smartboards) and software, that can include both audio and visual components, and can incorporate interactivity, including assessments with feedback. It also includes virtual classrooms, social media, computer-based personally adaptive learning, web-based instruction, and instructional materials. Unlike live radio and TV, these platforms are often provided as on-demand services that students can access at any time, either online or offline. In some forms of e-learning, the students interact with the technology individually (e.g., at-home programs, or in computer labs)—we refer to these as "computer assisted learning" (CAL) interventions. In other forms, the technology is a tool used by a teacher or facilitator (e.g., TVs in classrooms)—we refer to these as "computer-aided instruction" (CAI).

In the past, each category of intervention would map fairly directly to specific technologies. For example, audio interventions used radios; video interventions used televisions; and e-learning interventions used computers. Over the years, these lines have been blurred and individual technologies can encompass multiple features; for example, smartphones can now provide audio and video content, e-learning, and videoconferencing in one or several apps.

Distance learning programs or interventions include features that vary quite widely. While the category or technology is one modality dimension, there are many other dimensions for how the technology is used. Table 1 lists common features found in distance learning interventions.

Table 1: Distance Learning Features

FEATURE	OPTIONS
Target population	**Level:** Pre-primary; primary school; secondary school; or tertiary, vocational, technical **Enrolled:** In-school, out-of-school students. **Special needs vs General:** The content may or may not be accessible to those with special needs; alternatively, it may be designed to explicitly address special needs.
Content	**Academic Subjects:** Subjects include Math, Language, Science, Social Studies, etc. **Non-Academic Subjects:** Content can cover social and emotional learning outcomes, life skills, entrepreneurship, technical, vocational, or professional. **Language:** Content can be delivered in an education system's official language, the native language of the learners (if different), or in a new language that is being taught. **Context:** Content can explicitly make local geographic and cultural references, or attempt to be context-neutral.
Pedagogy, Activities	**Instruction:** Technology can serve as an instructor, teaching new facts, concepts, and skills through lecture, demonstration, or illustration. **Practice:** Learners can practice solidifying concepts or skills through practice problems and quizzes; or through more interactive means such as games and stories. **Application:** Learners can build deeper conceptual understanding and hone skills by applying concepts to new problems.
Exposure	**Duration:** How long (days, weeks, months years) the program lasts. **Intensity:** How often students interact with the technology and the duration of each interaction.
Content level/ pacing	**Static:** The content and pacing are pre-determined. **Curriculum-based and paced:** The content is designed to integrate with the regular school curriculum, by either delivering content from the curriculum or providing content that supports the curriculum. **Adaptive to student learning levels:** The technology assesses user learning levels and trajectory and delivers content appropriate for their level and pace, regardless of the curriculum. **User-determined:** The user determines which content to review and progresses at their own pace.
Technology	**Device:** Radio, TV, Computers, Tablets, Smart phones, Simple phones, and "Smart boards" **Infrastructure:** TV or radio broadcast, cellphone signal or coverage, broadband, electricity.

Table 1: Distance Learning Features

FEATURE	OPTIONS
User	**Instructor or Learner:** The user of the technology can be either the learner(s) (as with computer-assisted learning, or individual use products), or an instructor or facilitator (as with computer aided instruction). **Facilitated or self-led:** A facilitator can walk learners through content (either directly—if they are the user; or indirectly—if learners are the users), or help learners with the content; or users of the technology may be largely left free to interact with the technology themselves. **Individual or group:** When learners are the users, they can interact personally (one-on-one) with the technology or as part of a group.
Synchronous or Asynchronous	**Live or pre-recorded:** Content can be delivered by a person in real-time (synchronous), or it can be pre-recorded, or pre-loaded on devices (asynchronous). This often interacts with pacing and whether there is a live instructor. For synchronous learning, the technology is just a medium for connecting learners and instructors. For asynchronous learning, content is stored and delivered using the technology.
Complementary Activities	In many distance learning programs, the technology is only a part of program design. The program may also include group discussion, and group or individual activities such as homework or in-class activities.

As Table 1 suggests, interventions may be simple and only provide students or teachers the technologies, with no further structure or support. And the technology can just be a method for instructors and learners to communicate. However, most programs include predetermined content, facilitation and/or complementary activities.

1.2 Simple Conceptual Model of Learning

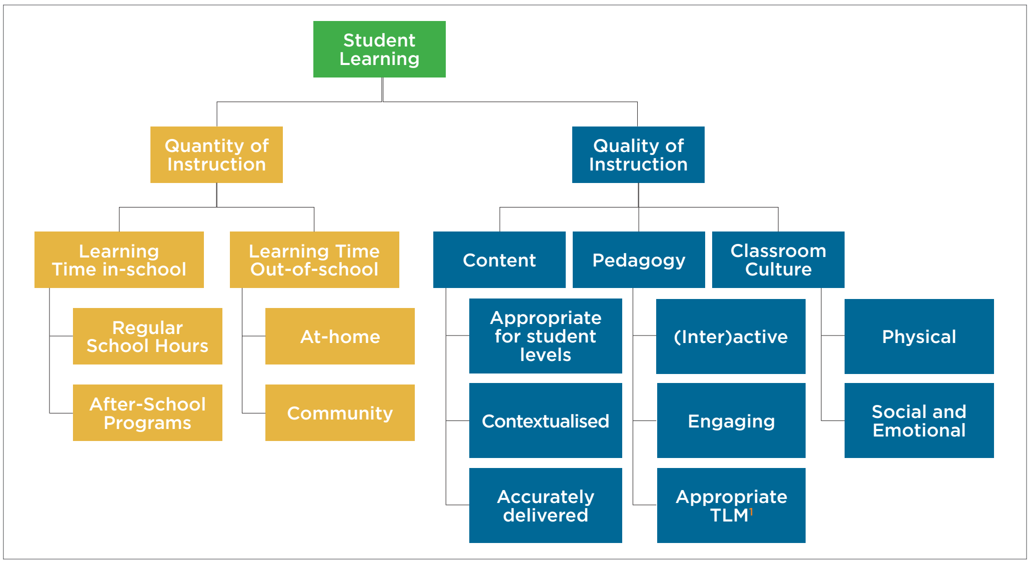
We believe that the question of which technology is most effective (or variants such as which technologies work, which technologies have the most robust evidence base) is somewhat misplaced. The success of any intervention depends on three factors: the baseline conditions, whether the intervention is conceptually sound, and how well it is implemented (Bates and Glennerster 2017). To understand, conceptually, how distance learning can be effective, it helps to have a theory of what leads to student learning. We use a highly simplified model: how much students learn is a function of how much time they spend learning, and the quality of instruction to which they are exposed (Filmer et al. 2020). The quality of instruction can be thought of as "productivity," or the amount of learning per time.

$$\text{Total Learning} = \text{Total Hours of Instruction} \times \left(\frac{\text{Learning}}{\text{Hour of Instruction}}\right)$$

This simple framework implies that there are two main pathways for distance learning to influence learning. First, distance learning can increase the quantity of learning by increasing instructional time.[1] Second, distance learning can improve the quality of learning by changing, and improving, how limited in-person classroom time is used. Interventions can obviously improve both quantity and quality.

Figure 1 summarizes the pathways through which instruction leads to student learning.

Figure 1: Conceptual Model of Learning



1 Teaching and Learning Materials

What is understood as high-quality instruction?

While increasing in-school and out-of-school instructional time is conceptually simple to execute, improving quality instruction is less obvious. Evidence shows that certain teaching practices contribute to better learning outcomes for students, specifically those that are more engaging, more interactive, incorporate assessment and feedback, and those with content that matches the learning level of students (Banerji et al. 2018; Stockard et al. 2018; Muijs et al. 2014). In many countries, teacher effectiveness varies widely due to teachers' lack of knowledge, unproductive attitudes, and poor teaching practices. It is not uncommon for teachers to deliver content poorly (e.g., practicing rote learning) or incorrectly (Bold et al. 2017).

Distance learning tools offer an opportunity to ensure the delivery of consistent quality content, as well as interactive and (for those technologies that are personalized) adaptive instruction.[2]

1 This can be in-school or out-of-school. Technically, the amount of learning a student is exposed to includes not only the number of hours of formal instruction, but also time spent in after-school education programs and time spent doing homework or other non-formal educational activities.

2 While personalized, adaptive instruction has been found effective in many studies (Banerjee et al. 2016; Muralidharan et al. 2018), these studies did not disentangle the effect of adaptivity, per se. Klaveren et al (2017) through an experimental study, found that a personalized adaptive computer assisted learning program fared no better than a static computer assisted learning program. However, this appears to be an outlier, as in this study, the static instruction was of exceptionally high quality.

Distance Learning Evidence

Method

In reviewing and distilling the evidence, we chose to include only rigorous impact evaluations—sufficiently-powered[3] experimental or quasi-experimental studies (with the addition of a few metanalyses that include non-experimental studies), which look at learning outcomes, and where authors discuss the program or theory in sufficient detail to understand how or why the program would improve learning outcomes (or fail to do so). See Appendix A: Review methodology and data collection for a description of our methodology and Appendix B: Summary of studies included in the Distance Learning Evidence Review for an overview of the papers included in this review.

Evidence Overview

As detailed in and Table 1, distance learning programs vary widely in terms of technologies used, the infrastructure required, who the target population is, which subjects are covered, whether content integrates with the regular school curriculum or whether they provide personalized content to students based on their learning levels, who the user is, whether activities are facilitated, whether there are complementary activities such as group-work or individual homework assignments, as well as their respective quality of content and implementation. At a high level, our review has revealed three not too surprising findings:

- In most cases, programs that increase the total amount of time students are learning, for example, through instruction or homework, successfully improve learning outcomes.

- Distance learning interventions that displace status quo instruction will only have a positive impact if they are higher quality than the status quo.

- For either to work, they must be implemented well.

Quantity-wise, students may receive additional instructional time in front of radio, TV, phones, or computers (individually or in groups), on the school premises, after regular school hours (facilitated and unfacilitated), or at home. For example, in India, a CAL program provided remedial tutoring sessions as a complement to regular in-class Math classes for students in schools run by Gyan Shala, an educational NGO (Linden 2008). Under the guidance of supervisors, students would complete short CAL sessions after school. The program improved learning levels of students.

Quality-wise, distance learning tools may change how status quo instruction is delivered. In these cases, students may receive higher or lower quality instruction when distance learning tools displace regular instruction. They have a high bar to

3 Studies with sample sizes large enough to detect impacts. We distinguish between small-sample studies that find large impacts and are statistically significant (which we include) and small-sample studies that fail to show statistically significant impacts, likely because they are underpowered (which we exclude).

clear if the quality of normal in-person instruction is already high. For example, in India, the same researchers as above evaluated the same Gyan Shala CAL Math program as an in-school program. They found that students who experienced the CAL program instead of the normal high-quality instruction performed worse than students who did not receive the treatment (Linden 2008).

Quantity and quality considerations are not just determined at the program design stage. Both can be affected by implementation, which depends on the appropriate “enabling environment”. If a distance learning program requires consistent electricity or internet access, or require that learners be within broadcast coverage, and those infrastructure prerequisites are either not in place or are unreliable, the intervention may unintentionally reduce total instructional time and lower relative productivity compared to the status quo. For example, an interactive television intervention in Ethiopia that was designed to fill major gaps in teacher quality failed to improve Math scores for students; researchers attributed the lack of impact to frequent power interruptions that prevented classes from having regular access to the intervention (Assefa 2017).

Overall, programs can succeed or fail—where success is defined as positive impact relative to the status quo, and failure is defined as no or negative impact—for multiple reasons. But before discussing the evidence in detail, it is worth noting that the goal of distance learning is not always to be more effective than in-person instruction. If the intervention is just as effective as in-person instruction, but cheaper to implement (or more scalable), it will be more cost-effective. This can be the case when schools decide to implement online versions of in-person courses to expand access to those courses. For example, in six universities in the United States, researchers found online and in-person instruction equally effective, and demonstrated that in the long-run, the online courses would be far more cost-effective (Bowen et al. 2012).

We divide the rest of this section into two main sub-sections: (1) programs intended to increase instructional time relative to the status quo and (2) programs that replace (substitute or displace) status quo instruction. Each of these sub-sections is further subdivided into examples of programs that had a positive impact and those that did not.

2.1 Programs that Supplement The Status Quo

Many children do not have access to traditional instruction. And for many who do, and who are officially enrolled, traditional instruction is insufficient to ensure that they learn what is expected by local and international standards. The conceptually simplest solution is to increase the amount of instruction these students receive.

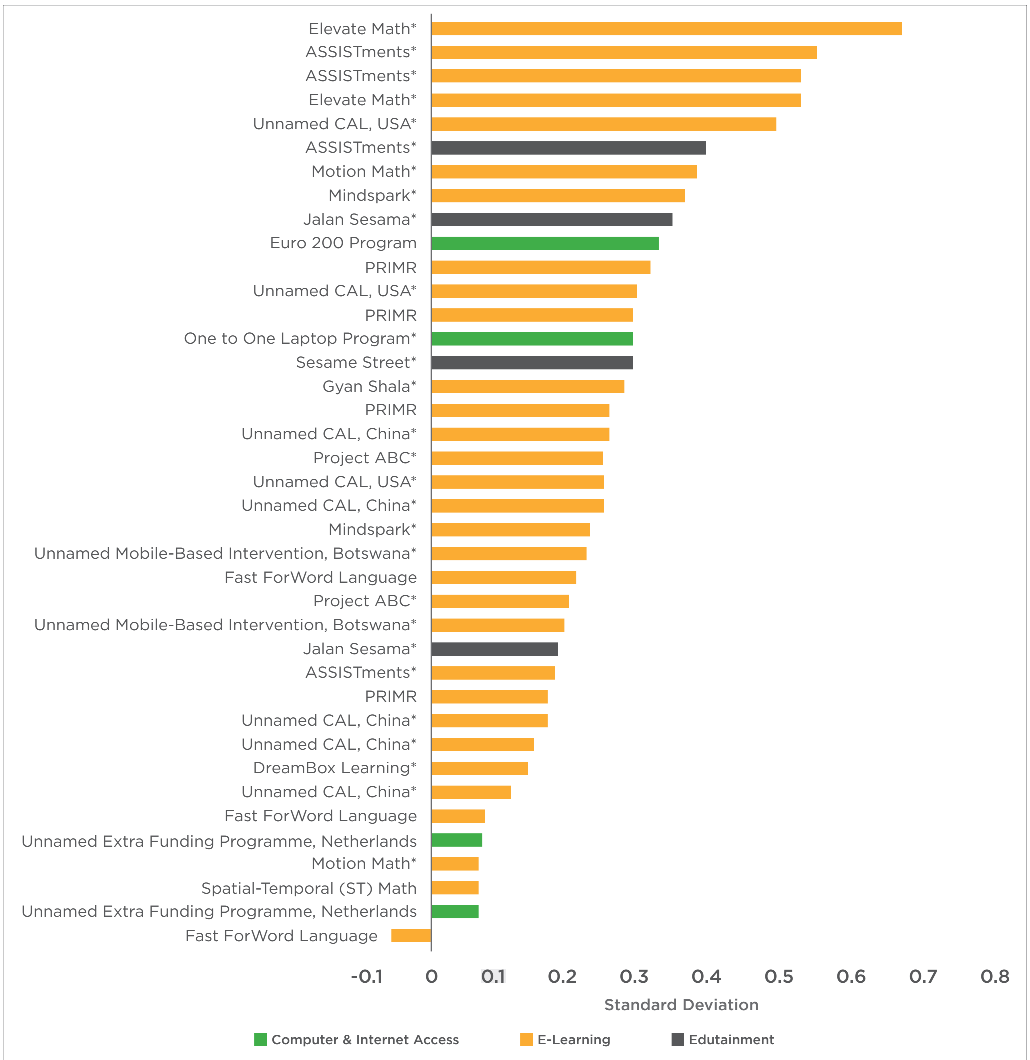
There is considerable evidence on different afterschool and out-of-school distance learning interventions, however one notable omission is that on radio instruction. Radio is arguably the most widely available technology to deliver educational content for out-of-school students or during school closures. According to a UNESCO report in 2012, at least 75% of households have access to a radio. However, most of the rigorous evidence on audio instruction has come from in-school programs (discussed in Section 2.2 Programs that replace status quo classroom instruction).

The evidence on distance learning interventions designed to increase instructional time that does exist is relatively consistent; the main takeaways include:

- After-school and out-of-school programs have been particularly effective at increasing learning.

- In rare cases, supplemental programs did not improve learning either because they failed to increase instructional time, or due to exceptionally poor design and implementation (e.g., lack of infrastructure or insufficient oversight).

Figure 2: Effect Sizes of Supplemental Distance Learning Programs, by Technology



Note: * indicates that the effect size is significant at the 5% level. In case of an effect size range, the graph displays the mean.

2.1.1 Supplemental Programs that Increased Learning

Most programs that intend to increase instructional time manage to do so effectively, hence the pathway for improved learning is relatively straightforward. We therefore choose the simplest method to present evidence on these programs, categorizing them by the technology used. We still share some of the features that might determine their quality, as quality determines how effective these interventions might be. During our review, we observed that most successful distance learning programs were conducted in controlled or semi-controlled environments which contributed to their success. Features of controlled and semi-controlled environments include recording student attendance, conducting distance learning at a school laboratory, and having teachers supervise the learning sessions to ensure adherence to the distance learning intervention.

Edutainment

More than 50% of children are not enrolled in preschool the year before primary school (World Bank). Edutainment programs, such as those developed by Sesame Street Workshop and Ubongo, were developed as a response to large gaps in school readiness (Kwauk et al. 2016; Borzekowski et al. 2010).

Video: Research of edutainment programs delivered to preschool-aged children consistently demonstrate positive impacts on school readiness—in particular, basic math and language outcomes such as number and letter recognition. While several of the studies in this review were conducted within preschools (among students already enrolled), the comparison group did not participate in academic activities during the same time. Relevant experimental evaluations of video interventions are described below.

Two experimental evaluations of Akili and me video content by Ubongo in Tanzania and Rwanda studied the difference in learning outcomes between children who were exposed to a controlled viewing of Akili and me (treatment group) and children who viewed popular local children's programming (control group) five days a week for four weeks during the school day (Borzekowski et al. 2019). An experimental study in Turkey examined the cognitive effects of the childhood television program BOM on 5-year-old children. Experimental participants were asked to watch "BOM" every weekday for 13 weeks, while control participants watched another entertainment program (Baydar et al. 2008). In Indonesia, authors studied the effect of a 14-week intervention on children aged three to six who watched three or four episodes of Jalan Sesama a week and compared it to a control group who watched another television program once a week (Borzekowski et al. 2010). Finally, a metanalysis of Sesame Street in 15 low, middle and high income countries studied learning outcomes among children who watched the program (Kwauk et al. 2016).

These studies showed significant impacts on student outcomes. Authors credited "fun and engaging content—something that was not 'preachy or teachy'—and characters with whom children could establish an emotional connection," (Kwauk et al. 2016) especially in low-resource environments where students "lack sufficient support for early learning skills prior to beginning school," (Borzekowski et al. 2019) as well as the level of exposure (e.g., quantity) to the program (Baydar et al. 2008).

E-learning

Under the e-learning category of supplemental programs, we review interventions that use CAL, also known as individual-use products, which also include mobile-based instruction, and simple access to technology. Computer Aided Instruction (CAI) is typically not a supplemental intervention, rather one that teachers use during class time as an alternative to traditional instruction, and therefore discussed in the "substitute" section below.

As with other distance-learning solutions, e-learning interventions can address some hurdles students face that affect their learning. Specifically, e-learning can tackle the barriers faced by learners from underprivileged backgrounds who might have an inadequate learning environment and insufficient access to quality instruction (Lai et al. 2012). However, e-learning typically depends on high-tech devices and infrastructure, which is not prevalent in many contexts. Research of e-learning supplement programs have consistently shown that those which successfully increase instructional time tend to be effective at improving learning outcomes.

Computer Assisted Learning

Many CAL programs have been shown to improve learning outcomes by increasing instruction time. In some cases, the supplemental program included both CAL and in-person instruction. In other cases, CAL was a stand-alone component, but changed how traditional instruction was delivered. For example, in flipped classrooms, where lectures were delivered through the technology as homework, and class time was used for active learning activities, CAL typically substituted homework. Finally, CAL could be offered as a stand-alone intervention that did not interact with traditional instruction at all. In almost all cases, CAL provided practice assessments, and sometimes limited video instruction. More recently, particularly with online learning, CAL provides both instruction and assessments.

Supplemental CAL programs that incorporate supplemental in-person instruction: In India, an experimental evaluation of a 90-minute after school-program, 45 minutes of which used Mindspark, a personalized adaptive learning CAL product, found a positive impact in Math and Hindi tests scores over the 4.5-month implementation period. The program included both an in-person instruction and a Mindspark segment, which used adaptive assessments and limited instructional videos. The authors note that the CAL program not only provided additional instructional time as in other programs, but that instructional time was of higher quality, and therefore more productive, given the software's ability to tailor instruction to student learning levels, and provide interactive feedback. The implementation of the program was in a setting where an instructor could support adherence (Muralidharan et al. 2019).

Snipes et al. (2015) conducted an experimental evaluation on the Elevate Summer Math program, a 19-day intervention for eighth grade Algebra students that incorporated three hours of in-person instructional time per day, plus one hour of Khan Academy learning tool per day. Treatment students who took the program in the first half of the summer performed considerably better on a standardize exam relative to control students (who participated in the program in the second half of the summer, but were assessed before participating).

Supplemental CAL deliberately integrated with traditional instruction: Three experimental evaluations on the impact of the ASSISTments online homework support program found positive impacts on Math learning outcomes for seventh and eighth graders in the United States. ASSISTments provided practice Math questions, and in some experiments, instruction and questions with hints and feedback. In two of the evaluations, feedback and instruction helped students better understand concepts, their learning levels, and mistakes. The duration of the program varied from one week to one year. In all experiments, the data from the software on student levels of understanding was shared with teachers and helped teachers adapt instruction accordingly. (Singh et al. 2011; Kelly et al. 2013; Roschelle et al. 2016).

In Norway, researchers examined the effectiveness of a "flipped classroom" where traditional learning is done via online videos with classroom time used for more active/collaborative learning methods. The study was done in two parts. In 'study 1' students mostly worked individually during class time. In 'study 2' the inverted classroom had all students working on the same course unit at the same time in groups. The control group received traditional lectures. Results of study 1 showed no significant difference in performance between students in flipped classrooms compared to traditional classrooms. However, results of study 2 showed higher performance in test scores in the flipped group compared to the lecture group (Foldnes 2016).

CAL stand-alone program: An experimental study of DreamBox Learning, found positive impacts on Math scores of kindergarten and first grade students in the United States. DreamBox Learning provided students with adaptive assessments and instruction for between 20 and 40 minutes each day in either an in-school online learning lab or an after-school lab over four months. Control group students used the in-school learning lab for literacy instruction (and therefore the program did not substitute traditional math instruction). Authors could not "isolate the effect of DreamBox from the effect of additional instructional time." While the program also provided feedback to teachers on student understanding, in this experiment teachers did not modify instruction accordingly (Wang et al. 2011).

Linden (2008) conducted an experimental evaluation of the one-year after-school Gyan Shala CAL program in India. The program was designed to complement the days' math curriculum for children in grade two and three with one hour of practice questions. It found positive impacts when offered as a supplement.[4]

In a series of experiments, Lai et al. (2012, 2013) found two CAL interventions offered to elementary public school students in poor rural areas in China had positive impacts on Math and Mandarin language, respectively. The programs, designed to complement the regular in-class curriculum, offered remedial after-

4 A prior evaluation described in the same study, a substitute version of the program found negative impacts.

school instruction, games and practice questions twice a week, for 40 minutes each session, for one semester. Mo et al. (2015) studied the same remedial Math game-based program, also held outside of school hours in rural boarding schools for students in the third and fifth grades over one and a half years, and found that the impacts measured in Lai et al (2013, 2015) persisted.

Researchers in the United States evaluated the use of an iPad, iPhone and iPod app called Motion Math, a game whose goal is to improve the learning of fractions among fourth graders. Students in the treatment group played the game daily for 20 minutes over five school days whereas those in the control group had Math instruction deliberately excluding fractions. Students in the treatment group had a significantly higher knowledge of fractions after the intervention, as measures by a mid and post-test (Riconscente 2013).

In the United States, a five-year evaluation of a CAL program delivered to elementary students showed improved student learning outcomes in Math, Reading and Language. Students were randomly assigned to be part of a class that was taught seven to 20 minutes per day (depending on the grade) of a CAL curriculum in either Mathematics, Reading, and Language Arts (or some combination). The CAL "drill-and-practice" curriculum consisted of exercises and practice questions (but no instruction). Students in the language-only group served as the control for the Math-only group, and vice versa. There was also a pure control group which was not experimentally determined that received traditional instruction. For this latter comparison, we would consider this a substitute program (Ragosta et al. 1982).

Mobile Text and Voice-based Interventions

Mobile-based interventions use mobile devices and delivery content or practice through text, audio, video or voice. Research on mobile teaching has shown positive impacts on learning gains by increasing the level of engagement students have with the learning material and increasing the amount of time students spend learning. In most cases, the mobile device served as a supplement to traditional homework activities.

In Niger, a mobile-based intervention, Project ABC, was added on top of an existing two-year adult literacy program to a randomly-selected group of women. The intervention improved adult literacy skills of women relative to a control group that received only the status quo program. The intervention involved providing adults with a mobile phone and teaching them how to recognize numbers and letters on the phone, how to make and receive phone calls, and how to read SMS. Researchers noted that the increase in adult literacy was driven by increased teacher effort, greater student attendance, and additional time spent on learning activities (Aker et al. 2012).

An on-going experimental study in Botswana is examining the use of text messages and phone calls as a substitute to traditional schooling during the CoVID-19 pandemic. The first wave of results show that after four weeks, the interventions with just SMS and one with SMS and phone calls both resulted in cost effective learning gains. Researchers suggest that results might have immediate policy relevance and long-term implications for EdTech as a substitute/supplement to traditional learning (Angrist et al. 2020).

In Turkey, a difference-in-differences study on the use of mobile phones in language learning found that devices help learners improve their vocabulary. The evaluation aimed to explore the comparative effectiveness of supplementary materials delivered through three different means: mobile phones, webpages, and in print form. There were two treatment groups and one control group. Treatment group 1 was assigned mobile phones, treatment group 2 was assigned webpages, and the comparison group was assigned printed handouts. Each group received regular classroom activities supported with either mobile phones or webpages for the treatment groups and printed handouts for the control group over the course of four weeks. This study showed that carefully designed instructional materials for mobile devices can display information-rich content in the form of visual representations, textual information, audio, and animations, and improve learning outcomes. Furthermore, these impacts persisted one month after the treatment. (Saran et al. 2012).

Computer Access

Whereas CAL and mobile-based interventions have been shown to improve learning outcomes, some students do not have access to a laptop or mobile device and are thus unable to gain from such interventions. Therefore, there have been some interventions that aim to equip each student with a device that they can used to learn. Most evaluations looking at increased access to technology fail to find positive impacts (discussed in the next section), largely because unstructured access, per se, tends not to increase instructional time. One notable exception is if access is combined with a controlled environment where students are more likely to use the devices for educational purposes rather than for other uses such as entertainment.

A matching difference-in-differences study in the United States found that a one-to-one laptop program improved English Language Arts (ELA) test scores of third and fourth-grade students. Students in the treatment group were provided with laptops for two years, and given opportunities to use the laptops in class and at home, whereas those in the comparison group were not given a laptop. The laptop group mostly used laptops for writing papers and looking up educational information on the internet. After two years, students who were provided with laptops outperformed the students in the control group and had a higher ELA total test score and higher scores in the two subtests that correspond most closely to frequent laptop use: writing strategies and literary response and analysis (Suhr et al. 2010).

2.1.2 Supplemental Programs that did not Increase Learning

Programs that intended to increase instructional time, but failed to improve learning outcomes, require a bit more exploration. Overall, some fail to increase instructional time at all—either because they failed to substantially increase access, or because learners did not respond as anticipated, often using the technology for unproductive activities.

Programs Can Increase Access Without Increasing Instructional Time

Some programs that were designed to increase access to technology, in hopes of getting students to spend more time studying at home, tended to fail in the first steps of their theory of change—they did not increase the amount of time spent learning, and some failed to even increase access. Some programs supplied computers for home use, others supplied computers for schools, and others provided or improved internet access either at home or at school. Of the programs on this list that successfully increased access, the technologies were often used for non-academic purposes.

Computer Access

Theoretically, computer access can improve learning outcomes by either increasing the time spent learning (e.g., by completing additional educational activities on the computer) or by increasing the quality of learning (e.g., by interacting with educational software that is tailored to student learning levels). However, computers may serve as a distraction resulting in reduced time spent interacting with educational material. Below, we discuss examples of computer access interventions that failed to increase instructional time and, as a result, did not improve learning outcomes.

A quasi experimental study in the Netherlands on the effects of subsidies for computers and software for under resourced primary schools had null and mildly negative results from standardized testing in language, arithmetic, information processing, and world orientation. Researchers indicated that the computer subsidy was not used to buy extra computers or replace old ones, but some schools did buy new software or internet connections (Leuven et al. 2007).

A quasi-experimental study in Romania found that a voucher program to subsidize the purchase of home computers for low-income families with school children had largely negative effects on learning outcomes. Researchers suggest that implementation challenges likely led to the negative impacts. Although the Ministry of Education encouraged the use of these computers for educational purposes, “few children had educational software installed on their computer, and fewer still reported using their computer for educational purposes.” Further, the authors noted that there was some evidence that, “computers were mainly used to play games,” and as a result, children “spent less time reading and doing homework.” (Malamud and Pop-Eleches 2011).

An experimental study in Peru that examined the One Laptop per Child (OLPC) non-profit initiative, which provided laptops to students from poor rural communities across the country, showed that the program increased access to computers significantly but did not increase learning in Math or Language. Researchers noted that the mechanism through which the initiative could improve learning did not work as it did not “alter the time allocated to reading or to doing homework” (Cristia et al. 2012).

An experimental evaluation of a program in the United States, which provided free computers to secondary school students found no impact, according to the authors, due to computers not increasing the amount of time spent learning. “High levels of use of home computers for games, social networking, and other forms of entertainment have raised concerns about the displacement of homework time” (Fairlie and Robinson 2013).

Internet Access

Internet access may increase the amount of time students spend learning via online content such as educational YouTube videos, massive open online courses (MOOCs), Wikipedia, and other online educational content. However, access to online educational material does not always translate to productive study time. A quasi-experimental study in England on the impact of differences in broadband connection speeds on primary and secondary students’ learning outcomes had null findings. Researchers noted, “while ICT upgrades appear to increase student consumption of online content, we find no significant effects on student time spent studying online or offline, or on the productivity of time spent studying” (Faber et al. 2015).

Supplemental Programs Can Fail Due to Poor Implementation

Implementation challenges can cause even supplemental programs to be ineffective at improving learning outcomes. Specifically, if the users of the technology do not know how to, or otherwise choose not to use the technology appropriately, the time spent with the technology can be completely unproductive.

A study on the effect of the provision of three ICT interventions—e-readers for students, tablets for teachers, and tablets for instructional supervisors—on literacy outcomes among second grade students in Kenya found little to no impact. Researchers cited implementation challenges as teachers were not well versed with all the capabilities of the ICT devices to use them to their full potential (Piper et al. 2016).

Supplemental Programs Can Fail Due to Inappropriate Content and Pedagogy

If the content and pedagogy are inappropriate for the target population, we should not expect to see positive impacts.

In the US, two studies on the effects of the Fast ForWord computer-based language training program for reading comprehension and language learning on students grades K-6 found no effects or small effects in the treatment groups compared to the control groups. While researchers cited poor implementation in the first study, researchers from the second study noted that the software was designed for students with auditory or other learning disabilities, and the content and pedagogy were inappropriate for a more general student population (Rouse et al. 2004; Borman et al. 2009).

A study conducted in the United States evaluated the effectiveness of a supplemental Math program called Spatial-Temporal (ST) math among students in second to fifth grade. Treatment students received an extra 90 minutes of Mathematics instruction compared to students in the control group. The study found a negligible effect of the program on Math scores after one year and slightly larger but statistically insignificant effects after the second year. Researchers noted that part of the reason for the program's failure is content being at the wrong grade-level for students. Particularly, the lowest performing students were unable to access content they needed that was below their grade level. Therefore, programs that serve students who are below or above their grade level "may be more effective in increasing students' mathematics gains by including content outside the student's school grade and/or provide a truly adaptive program with different start-points" (Rutherford et al. 2014).

2.2 Programs that Replace Status Quo Classroom Instruction

In many cases, practitioners implement distance learning to fill a quality gap in the status quo. For example, there may be no qualified teachers to teach a particular subject, or, put another way, teachers may be underqualified. Alternatively, teachers may simply fail to show up during class time, fail to spend time teaching or fail to teach effectively (Chaudhury et al. 2006; Bold et al. 2017). In cases of poor teacher performance, distance learning can serve as a substitute for the ineffective teacher. In other cases, teachers do not have appropriate teaching and learning materials (e.g., chalkboards, materials for science labs, visuals, textbooks), and the distance learning functions as a substitute for missing or sub-par TLM. Success of any of these interventions depends on having the necessary infrastructure as well as adoption by the education system, which likely requires adequate training.

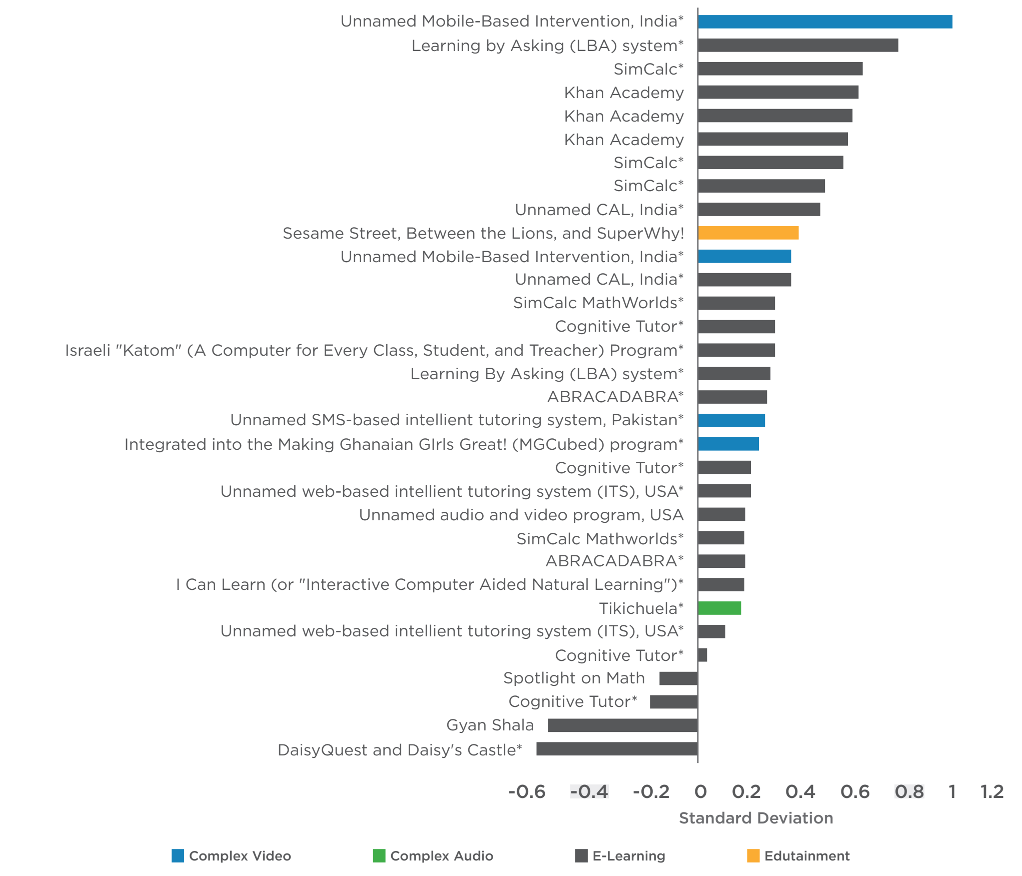
Therefore, distance learning can improve quality if it standardizes the quality of instruction delivered by ensuring accurate and appropriate content, tailors to student learning-levels, uses engaging pedagogy, improves interactivity, or provides feedback to students to facilitate learning. Success also depends on the relative quality of status quo instruction versus what is offered by distance learning interventions. Programs that displace the status quo instruction with distance learning have mixed results. Main takeaways from this review include:

- Successful interventions delivered higher quality or more appropriate content, instruction was engaging, personalized, adaptive and/or interactive. Unsuccessful programs provided instruction that was equal or lower in quality than the status quo.

- Some successful distance learning programs catalyzed additional teacher and learner effort, while others that were unsuccessful depended on additional learner effort, which failed to materialize.

- Some distance learning programs failed to increase learning simply due to insufficient infrastructure or poor implementation.

Figure 3: Effect Sizes of Substitute Distance Learning Programs, by Technology



Note: * indicates that the effect size is significant at the 5% level. In case of an effect size range, the graph displays the mean.

2.2.1 Substitute Programs that Increased Learning

When distance learning substitutes for traditional instruction, it can be effective if it overcomes teacher capabilities and capacity constraints, or alternatively when it catalyzes additional teacher effort.

Video: Edutainment

While edutainment has been shown effective on its own or when compared to non-academic instruction, it has also been used to substitute regular instruction—particularly in preschool. Children from lower income backgrounds are less likely to start kindergarten with foundational literacy skills compared to their peers from more advantaged backgrounds. Research has shown that this gap is not closed by elementary education (Garcia and Weiss 2017). Edutainment programs targeted at preschool children may teach children foundational literacy skills such as letter recognition and address the literacy gap that disadvantaged children face early on. In the United States, researchers studied an early literacy intervention in which schools were randomly selected to view clips from Sesame Street, Between the Lions, and SuperWhy! for 10 weeks. An experimental evaluation showed that, under conditions that the authors "considered to be ideal", the program improved children's ability to recognize letters, letter and word sounds, and concepts of story and print (Penuel 2012).

Simple Audio and Video-focused Programs

The design of successful programs that substituted regular instruction tends to vary—from those that only implemented a content-only platform such as an Interactive Radio Instruction (IRI) and TV, to those that added extra activities or components of pedagogy. Tying them together, they were all designed to overcome challenges of teachers' knowledge gap, teaching style, lack of emotion, and to foster standardized engaging instruction.

Interactive Radio Instruction (IAI): IN Zanzibar, Tanzania, an IAI program, Tucheze Tujifunze, provided three 30-minute sessions per day in school for nine months, and covered life skills, Kiswahili, English and math. The content was integrated with "songs, stories, riddles, games and other creative and cultural based activities." The difference in differences studies found positive impacts of the program in all three subjects after 9 months, and differences persisted 6 years later. The authors claimed "IAI remains a viable type of intervention for increasing access to high-quality early education, particularly in the most challenged districts" (EDC 2009; RISE and ZTUR 2015)

In Somalia, researchers studied the USAID-funded Somali Interactive Radio Instruction Program (SIRIP) which provided roughly 3 hours of interactive audio programs per day to 330,000 children in Grades 1-5 attending formal, nongovernment, Koranic, and community schools. A non-experimental evaluation found that grade one SIRIP learners scored higher than non-SIRIP learners on standardized literacy tests and in Math (EDC 2012).

Mobile Phone: A quasi-experimental evaluation in India of the BridgeIT program that provided mobile-based instructional videos and activities to help fifth and sixth grade students in English and Science learning, showed a statistically significant effect in student learning of both subjects. The treatment students were shown about 3 videos per instructional week for each syllabus, subject and standard for an academic year. Researchers attributed this effect to the technology being a catalyst for change in pedagogy and an "accelerator" of alternative teaching practices that improved student learning (Wennersten 2015).

CDs: In Paraguay, an experimental evaluation of the Big Math for Little Kids program, which delivered math instruction through audio lessons on CD for 4 hours per week over the course of the academic year, showed that students who received the program significantly increased their performance in Math. More substantial effects were found for students with lower initial test scores. Researchers suggested that the program's increased use of activity-based teaching, increased pacing (hence appropriate for student learning levels) and engaging delivery drove learning gains (Naslund-Hadley et al. 2014).

More Complex Successful Audio and Video-focused Programs with Complementary Activities

Some audio and video interventions involve additional activities such as teacher training or interaction between the instructors and students. Research has shown that more complex audio and video interventions improved quality, but not necessarily directly. In one case the intervention changed teacher and student effort in response to the technology and accompanying training. In another case, a live video instructor in essence increased the number of teachers in the classroom. A CAI program in Pakistan that provided multimedia video presentations, combined with intensive teacher training, on grade-level Math and Science content resulted in significant improvement in learning gains. The program, exposed the treatment group to 29 hours of video content over the school year. Authors credited increased teacher and student effort and the intervention's ability to "overcome teacher capacity constraints" (Beg et al. 2019).

Researchers in Singapore evaluated the effectiveness of science lessons that were designed to be delivered via mobile devices with the guidance of a teacher. Smartphones using "GoKnow Mobile Learning Environment software", gave students access to 21 weeks of lessons which is equivalent to 1 years' worth of content. Students in the control group were taught in the traditional way. Students in the treatment group performed better on traditional assessments and were also found by the authors, "to learn science in personal, deep and engaging ways as well as developed positive attitudes towards mobile learning" (Looi et al. 2011).

An interactive TV instructional program in Ghana, Making Ghanaian Girls Great! which broadcast two hours of daily live lessons (one hour math, one hour for English) to rural primary school students in Ghana led to significant gains in rural students' Math scores, numeracy, and foundational literacy skills. The program was designed to mitigate the challenge of how to "attract and retain professionally trained teachers". Authors claim success was not due to increased time on task by the primary instructor, nor different pedagogies used, but perhaps by better classroom management and the fact that the virtual classrooms had, in effect, two teachers (the video instructor and a local facilitator) as opposed to the status quo, which had only one teacher (Johnston et al. 2017).

Computer-Assisted Learning: Interactive and Adaptive Software

CAL is arguably the most promising technology for changing status quo instruction. As with other technologies, it can deliver standardized, engaging, high-quality instruction, often through animations and games. Further, CAL instruction can be personalized and adaptive to individual student learning levels and trajectories. Whereas a teacher with a heterogeneous class can only deliver one lesson at a time, CAL can assess learner understanding and provide instant feedback—even for more complex problems; and it can deliver a steady stream of stimulating and encouraging messages to reinforce student motivation. Indeed, the evidence on CAL programs in schools is encouraging.

Successful programs that increased learning gains through focusing on delivering better pedagogical outcomes include programs that provided adaptive learning, interactive feedback and engaging/active learning. Researchers credit their success to the use of better pedagogy, and a more engaging, personalized, and/or blended-learning approach, with interactive feedback. Below, are examples of CAL interventions that had significant impacts on student outcomes.

Early Primary: An evaluation of a CAL-based phonological awareness program for kindergarten and first grade students in the United States compared learning outcomes between three groups of students: students who received computer-administered instruction, students who received teacher-delivered instruction, and the instructional technology control group who explored mathematics and drawing software programs. DaisyQuest and Daisy's Castle were the programs used to provide treatment students with instruction and practice in rhyme identification, phonological analysis and phonological synthesis. Each group received daily 20 minutes instruction sessions for 4 weeks. Phonological assessment scores were significantly higher among students who received computer-administered instruction and teacher-delivered instruction compared to the technology control group. The researchers conclude that CAL is an effective method for teaching phonological awareness to kindergarten and first grade students (Mitchell and Fox 2001).

Primary: A one-year CAL intervention in India aimed at improving the Math performance of fourth grade students by offering two hours of shared computer time a week during which students solved math problems at adapting levels of difficulty. The program increased Math test scores and the positive effects persisted over time. One year after leaving the program students who initially had low test scores did better than equivalent students who had not participated in the program (Banerjee et al. 2007).[5]

Two studies evaluated the use of a web-based Intelligent Tutoring System (ITS) on student reading and comprehension skills compared learning outcomes between students who learned how to read using the ITS (treatment) and those who learned traditionally (control). Students in fourth grade who used the ITS for 30 to 45 minutes per week over six months outperformed those who learned traditionally in reading comprehension (Wijekumar et al. 2012). Similarly, students in fifth grade who used the ITS for 30 to 45 minutes over six months outperformed those who were in the control group (Wijekumar et al. 2014).

In a study of the ABRACADABRA web-based literacy program for first grade students in Canada, students were randomly allocated to two CAL intervention groups, that were given computer-based literacy instruction using synthetic and analytic phonetics, and one control group that used a "balanced literacy" approach taught by the teacher. Students in the treatment groups received their respective CAL intervention for about 15 minutes a day, four times a week, and both groups saw significant improvement in literacy relative to the control group after 12 weeks (Deault et al. 2009).

Middle School: An evaluation of a CAI program, Interactive Computer Aided Natural Learning distributed by JRL Enterprises, in three urban school districts carried out over 2 school years in the United States compared learning outcomes between students who were taught algebra using CAI (treatment) and students who were taught traditionally (control). The CAI program divided lessons into 5 independent parts – a pretest, a review (of prerequisites needed for the lesson), the lesson, a cumulative review, and comprehensive tests. Students that failed the pretest or

5 This study both substituted and complemented standard instruction. One of the two hours was during class time, the other was offered during lunch of after school.

review were made to repeat the lesson until they received a certain degree of mastery. Students in the treatment group scored higher than those in the control group on an algebra test. The researchers hypothesize that individualized instruction from the CAI program contributed to the improved learning outcomes (Barrow et al. 2009).

An evaluation of the effectiveness of the Cognitive Tutor Algebra I program on students in the United States compared learning outcomes between students who were taught algebra using the program (treatment) and students who were taught traditionally (control). Learning outcomes, measured by test scores, were higher among students who were taught using the Cognitive Tutor program. Additionally, students in the treatment group had more positive attitudes towards Mathematics compared to those in the control group (Morgan and Ritter 2002).

Three evaluations in the United States (two experimental, one quasi-experimental) showed positive impacts of the SimCalcs program, in which some units of the algebra curriculum were replaced with a technology-aided version. The technology was used both for teacher training, teacher's delivery of concepts (CAI), and student interaction with technology (CAL). Teachers delivered content to seventh and eighth graders through visual representations and animations; the students engaged directly with the software by creating and analyzing graphs. Students who participated in the program performed better than those who did not, and learned more complex and conceptually difficult mathematics (Tatar et al. 2008; Roschelle et al. 2010).

Secondary School: An evaluation in the Netherlands studied the use of mobile games in learning. Students in the treatment group played history games for the whole day for a week to improve their knowledge on the history of Amsterdam while those in the control group received 2 class hours each day of regular lessons. Students in the treatment group gained more knowledge about medieval Amsterdam compared to those in the control group after a 1 week period because they had to actively work with the learning content (Huizenga et al. 2009).

Researchers in the United States conducted two studies to evaluate the effect of teaching algebra using SimCalc CAL software to deliver a 30 hour curriculum to 15 to 17 year old's at various points in the academic year and for various continuous lengths of days. The study was split into two with the first study being a randomized trial whereas the second was a quasi-experimental study. Both studies found that students taught using the CAL software had improved learning of algebra concepts compared to students who were taught traditionally (Hegedus et al. 2015).

An evaluation in the United States studies the use of the Cognitive Tutor Algebra I (CTAI) program in middle and high schools. Schools were randomly assigned to use the CTAI program or to continue teaching algebra traditionally for two years. The CTAI program exposed treatment school students to a self-paced individualized instruction system that used a personalized, mastery-learning, blended-learning approach. Algebra test scores found no effects in the first year. However, students who were taught using the CTAI program had higher test scores in the second year. This was statistically significant for high school students but not for middle school students (Pane et al. 2014).

Tertiary School: Two experiments were conducted to look at performance and satisfaction comparisons between undergraduate students taught using multimedia e-learning and those taught traditionally. There were three treatment groups in each experiment: a fully interactive Learning By Asking (LBA) group and a less interactive LBA group, both received forty-five minute online lecture and twenty-seven minute instructional video, and a control group which received a forty-five minute regular in-class lecture and review session. Results of both experiments showed that students performed better in the fully interactive e-learning group and had higher levels of satisfaction compared with the less interactive and traditional group. Researchers suggest that interactivity and feedback as well as the appropriate TLM and mode of delivery using the e-learning system led to the positive outcomes (Zhang 2005).

An evaluation in the United States studied the effects of interactive video, defined as: "the use of computer systems to allow proactive and random access to video content based on queries or search targets", on student outcomes. The study divided undergraduate students into three treatment e-learning environments (with interactive video, with non-interactive and without video), and a traditional learning control group. Results showed that learning performance and learner satisfaction in the group that had e-learning with interactive video was significantly higher compared to the other groups (Zhang et al. 2006).

Special Needs: In Israel, researchers studied the effect of the KATOM (A Computer for Every Class, Student, and Teacher) program on the spelling skills of children with disabilities. Students in the treatment group used laptops to learn while those in the control group did not. Researchers found that students in the treatment group significantly improved their spelling compared to those in the control group. The use of a computer made it easier for treatment group students to check for errors and get feedback (Eden et al. 2011).

2.2.2 Substitute Programs that did not Increase Learning

When distance learning displaces traditional instruction, it may not work when the content is either of lower quality by design, when it is implemented poorly, or when it depends on additional independent learner effort to maintain engagement.

Substitute Programs may not Improve the Status Quo if their Relative Quality is no Better (or Worse)

Programs that harness technology to displace traditional instruction show great promise when there are major quality gaps in the status quo. However, if traditional instruction is already of high quality, or if the technology solution provides relatively lower quality instruction, the intervention will have no, or possibly negative effects.

In India, an experimental evaluation of the Gyan Shala CAL in-school program found that students learned less than they otherwise would have learned when the program was used as a substitute, making it a "poor substitute for the teacher

delivered curriculum". The author noted that the program is more effective when it is implemented as a complement to the normal curriculum (Linden 2008).
A study in the United States evaluated the use of an introductory statistics interactive learning online course. Students were randomly assigned to classes taught in the traditional way (control) or using the interactive software (treatment). The study found no statistically significant differences in learning outcomes between students in the treatment and control groups. Additionally, students in the treatment group gave the interactive online format a lower rating compared to the rating the traditional format class got. They also found the course more difficult (Bowen et al. 2012).

In a small study in the United States, authors found a negative but not statistically significant difference in learning between middle school students taught algebra using CAL classes under the Cognitive Tutor's Bridge to Algebra program, and those taught with traditional instruction. Mediation analysis suggested that negative impacts were not correlated to classroom computers, access to the computer lab, and CAL materials (which were identified as challenges), but rather the relative quality of the teacher. The negative impacts were driven by classes that had certified teachers—where they were much more familiar with the traditional curriculum. (Cabalo et al. 2007).

In-school Substitute Programs Can Fail Due to Poor Implementation

Implementation failures can hinder the programs' ability to improve learning outcomes. These failures include: infrastructure challenges, insufficient teacher training and lack of student engagement.

Infrastructure: Examples of infrastructure challenges include power failure, internet connectivity issues, and limited access to equipment such as computers. Two experimental studies suggest that infrastructure challenges, among other factors, could explain the poor performance of remote learning tools.

In Brazil primary schools, an evaluation of the use of Khan Academy in School as a substitute to learning Math using traditional instruction found small positive effects on attitudes towards math. However, there were no significant differences on the average Math scores between the treatment and control groups. Researchers note that this was due to infrastructure problems, internet connectivity problems, and teachers not being motivated for the project (Ferman et al. 2019).

Teacher and student engagement: Inadequate teacher engagement, for example, insufficient participation or poor involvement, could result in the failure of educational interventions, particularly for interventions that depend on teacher engagement to be successful. Three research studies cited implementation challenges as teachers failed to incorporate the new technology into their classroom teaching.

In Colombia, an experimental study of the Computadores para Educar (CPE) program that installed refurbished computers in public schools and trained teachers on how to use computers showed no effect on students' academic performance. Authors claim is because the computers were used to teach students computer skills and were not used to teach any academic subjects (Barrera-Osorio, and Linden 2009). In a separate study of the Cognitive Tutor program in the United States, the authors found a negative effect of the CAL program on secondary school students' Math outcomes. Evidence from the studies suggests that a lack of familiarity with the approach and challenges to keep students engaged might have limited the impact of these programs (Pane et al. 2010).

A second experimental evaluation in the United States found that a blended classroom intervention had no statistically significant effect on student learning and achievement in ninth grade Algebra I. Researchers noted that low teacher participation and engagement during professional development sessions and low use of online student courseware, led to the lackluster results (Cavalluzzo et al. 2012).

Out-of-school Substitute Programs Can Fail if they Depend on Independent Student Motivation

Distance learning tools implemented out-of-school are those where students take classes at home or in non-school locations rather than attending normal classes in school. These out-of-school tools may not translate into learning gains because without the classroom climate, students likely lack the encouragement, discipline, and behavioral nudges (like predefined schedules and social norms) necessary to motivate them to sufficiently engage.

A study conducted in a community college in the United States comparing video instruction ("telecourses") and in-school courses determined that there was no significant difference in learning outcomes. The authors also evaluated student retention and satisfaction. While a majority of the students were generally satisfied with the telecourse, only 38 percent of the total enrollees completed the telecourse, with lack of motivation being cited as a large factor in dropout rates (Smith 1983).

In the United States, researchers studied the difference in performance of students attending live lectures of an introductory microeconomics course versus watching these same lectures in an internet setting. The experimental evaluation found modest evidence that live-only instruction dominates internet instruction. The authors suggest that students may have been tempted to defer instruction and cram for exam in online-only classroom experiences or had increased difficulty with listening to lectures in an internet setting (Figlio et al. 2010).

College students in virtual microeconomic classes in the United States performed significantly worse on the examinations than the live students. The authors noted that online students spent less time on course work and observed there might exist differences in the ways the students can interact with the problems in Microeconomics and other on-line materials. Ultimately, they argue that differences in student effort might explain the lower learning outcomes (Brown et al. 2002).

Similarly, a study that compared learning outcomes between Microeconomics students taught via a compressed hybrid teaching format to those taught traditionally. Students in the compressed format were offered one 75-minute class once a week over a 14-week semester while students who were offered the traditional format attended a 75-minute class twice per week. Both formats were taught by two experienced professors and had access to the same online material. Results showed that learning outcomes among students taught via the traditional format were higher compared to those taught via the hybrid format. With students in the compressed sections having only half the amount of face-to-face instruction as compared to those in the traditional sections, the study can be viewed as a “strong test of whether substantial differences in attendance matter to academic performance when online materials are also available.” Results of non-cognitive measures such as the proportion of classes attended or the probability of withdrawing from the class were insignificant (Joyce et al. 2014).

Another study in the United States evaluated the impact of different instructional models on the learning outcomes of college Microeconomics students. Students were randomly assigned to receive instruction via three modalities: in-person classroom instruction, blended instruction with a combination of online content and reduced instructor contact, and purely online instruction. All educational material was prepared by the same instructor for each of the modalities. The results show that learning outcomes, as measured by scores in a final exam, were higher for students who underwent classroom instruction compared to students who learned purely online. The reduction in test scores was more so for students with lower prior GPA scores, suggesting that much of the negative impact on student outcomes of those who participated in the online section is driven by below average students. Additionally, attrition was highest among students who were in the purely online treatment arm and was lowest among those who learnt via in-person instruction (Alpert et al. 2016).

In the United States, an evaluation of pre-laboratory sessions that were delivered via audio and visual podcasts loaded on mobile devices found no statistically significant difference on student performance between students who learned via the podcasts (treatment) and those who were taught traditionally via a lecture (control). However, there were positive significant results among students who had a high lecture participation. The researchers note that accessing the podcasts requires personal initiative, and thus highly engaged students were more likely to gain from the podcasts (Powell and Mason 2013).

While all studies were of post-secondary students in the United States, the link between increased independence and motivational concerns would likely exist in younger students or those in low income countries without adequate monitoring and support at home. Despite the fact that authors did not mention this as a

Recommendations

The extent and urgency of access to education and the level of global attention given to how to educate students remotely due to COVID-19 calls for more and better evidence-based action. Investments in distance learning will likely continue even after the pandemic subsides.

This review has found that most **interventions which increase instructional time are likely to improve student learning outcomes.** During school closures, therefore, something will almost always be better than nothing. However, comparing relative effectiveness across different intervention options is more difficult—largely because few studies have made these comparisons directly. Therefore, studies that compare distance learning to traditional instruction may be informative. Similar to our policy problem during school closures of deciding which program or intervention to choose among seemingly similar options, these "substitute" studies also explore the trade-off of more equivalent choices. The following recommendations were drafted to help decision-making during COVID-19, but are meant to generalize to a post-COVID world.

For **programs that substitute existing class instruction, we must consider the quality of instruction of the proposed interventions relative to the status quo.** We also need to understand likely pitfalls that would limit implementation and therefore limit or prevent program effectiveness such as poor infrastructure, or overreliance on student, parent and teacher effort. Policymakers should identify which challenges and constraints exist within their education systems and select an appropriate intervention to address their challenges, given existing constraints.

For example, if the policymaker's challenge is that teachers do not have the subject-content knowledge or pedagogical training to deliver certain content effectively, schools can replace traditional instruction with relatively simple interventions: centrally-produced audio or video that is broadcast to students. Turning to technological constraints, if radios are more prevalent than TV, as is the case in most Africa countries (Hudson et al. 2017), radio will likely be more effective. If TV is more prevalent, as is the case in India (Dasgupta 2016), TV might be a better choice. Global internet penetration and unique mobile phone usage, 59.5% and 66.6% of the global population respectively, are steadily growing into another avenue for delivering content remotely (Hootsuite & We Are Social 2021).

To tackle the more general problem of choosing, designing, and implementing distance learning interventions (whether during school closures or during normal periods), policymakers can follow three steps:

- Identify the specific education challenges (e.g., quantity of instruction, quality of content and pedagogy) and understand how technology can address those challenges, given contextual constraints (e.g., ICT infrastructure, device penetration).

- Design the distance learning intervention, including choosing the right technology to address the problem identified in Step 1 and determining complementary program features such as facilitation.

- Pilot the intervention to understand its feasibility and efficacy, evaluating its effectiveness at a larger scale, and once at scale, monitor the main activities of the intervention.

We describe the steps in detail in the following sections. While these steps aim to provide general recommendations, one of the objectives of this review is to create a framework which can be followed by country-specific briefs, where we will aim to dive deeper into the education challenges and contextual constraints to inform targeted recommendations.

3.1 Step 1: Identify the Need, Opportunities, Constraints

3.1.1 Need: Educational Challenges

An education system's need might be obvious to policymakers; alternatively, it may also require collecting information or perhaps conducting a formal needs assessment. Challenges faced by education systems include:

- **Out of school students:** Some students may not be enrolled in school by choice, because formal schools are inaccessible, or because students are displaced. Or schools may be closed (as is the case during the pandemic).

- **Teacher Shortages:** some schools may have more classrooms than teachers; or too many students per teacher; or may not have teachers able to cover some subjects.

- **Heterogeneous Classrooms:** Teachers may have students with varying learning abilities in the same class, perhaps because of different levels of preparedness or multi-grade classrooms.

- **Poor quality teaching:** Teachers may teach subjects for which they have low levels of subject content knowledge. Or they may be trained in or accustomed to using outdated and ineffective pedagogical practices, and perhaps are resistant to change.

3.1.2 Opportunities: Technological Solutions

After identifying the needs, policymakers can select interventions that can be implemented within their context. Several interventions can be implemented concurrently to provide structured learning programs to as many learners as possible, with each intervention better suited to address a particular constraint.

Table 2 below shows how technological solutions can be used to address these challenges.

Table 2: Educational Challenges, Characteristics of Low and High-Quality Instruction, and Potential Technological Solutions

BEST PRACTICE	CHALLENGE	POTENTIAL TECH SOLUTIONS
Quality content, accurately delivered	Teachers either do not know content or do not deliver it accurately	Distance instruction produced centrally and distributed through TV or Radio broadcast, internet, software, or physical media such as CDs, cassettes and flash drives, can ensure standardized quality
Contextualized content (appropriate language, level and examples)	Content is not the appropriate level, language, or is contextually inappropriate for some students	Textbooks and TLM are often procured centrally and disseminated throughout the education system. As long as schools or students have the appropriate technology (phones, radio, TV, other devices, internet access), **customized content can be developed and deployed electronically, through local TV, radio, videos, websites without needing to mobilizing an expensive distribution system.**
Appropriate level and adaptive to student learning levels	Students are at many different learning levels, but a teacher can only deliver one lesson at a time	Teachers' ability to adapt to each individual student is limited if they have many students in their class, especially if student learning levels vary widely. **Personalized CAL software can be adopted to deliver content that matches each student's learning level.**
Content that is delivered in an engaging way	Teachers' teaching style lacks enthusiasm	If designed well, with engagement in mind, engaging instruction can be developed and standardized. **Edutainment, Interactive Television and Radio Instruction, and interactive CAL instruction and games are particularly good for maintaining student engagement.**
BEST PRACTICE	**CHALLENGE**	**POTENTIAL TECH SOLUTIONS**
Interactive Feedback	Teachers do not ask students questions, or do not provide constructive feedback for answers, or discourage students from asking questions.	**Personalized CAL solutions can assess student learning levels and provide instant feedback**— both positive and constructive.
Active, and activity-based	Teachers primary activity is lectures and/or reading from the textbook	Technology can provide integrated, scripted delivery models for active and activity-based instruction. **Teachers can follow a "flipped classroom" model, using technology to deliver content, and class time to conduct activities.**

Table 2: Educational Challenges, Characteristics of Low and High-Quality Instruction, and Potential Technological Solutions

BEST PRACTICE	CHALLENGE	POTENTIAL TECH SOLUTIONS
Appropriate TLM	Teachers lack materials for lessons	**TV, CAI or CAL platforms can supplement lacking TLM or replace ineffective TLM.**
BEST PRACTICE	**CHALLENGE**	**POTENTIAL TECH SOLUTIONS**
Places of learning are comfortable (temperature, seating), and conducive to learning (noise, light, distractions)	Students are uncomfortable or have trouble seeing or hearing instruction	**Technologies can be mobile, allowing students to learn in more comfortable, quieter environments.** Note, however, that the home environment is rarely quiet and free of distractions.
Disciplined environments that demonstrate respect toward students, encouragement, high expectations and emotional support	Students lack confidence, ownership of learning and enthusiasm	Technologies can be designed to promote positive mindsets in students. **Positive reinforcement can also be built in through feedback and "gamification".**

3.1.3 Constraints: Pitfalls for Implementation

The effect of any intervention is dependent on context and implementation. With distance learning, infrastructure and access are key considerations as to whether an intervention is feasible. Programs may depend on existing penetration of certain technologies—for example, the proportion of households that own radios, TVs, or smartphones. And technologies themselves are dependent on underlying infrastructure—whether electricity is available or reliable in schools or households, or whether there are broadcast signals for radio, TV, or cell coverage, or internet access.

The success of an intervention is also dependent on student and teacher engagement. For example, poor teacher participation and limited student compliance may hinder the impact of these interventions.

3.2 Step 2: Choose the Technology, Design the Intervention

Based on findings from Step 1, policymakers should develop an intervention and implementation plan that adapts interventions to their specific context. This includes not only selecting the right technology, but also designing the content and accompanying intervention features, which can be found in Table 2, above.

As with understanding the contextual constraints, program designers should become aware of potential implementation pitfalls and how to overcome them. Interventions may rely on behavioral responses by instructors or students to be implemented successfully. If teachers are required to significantly change the way they do their job, adoption may require significant training and mentoring. If after adoption, the program requires more effort than business as usual, teachers may require additional monitoring and incentives to deliver the program with fidelity.

Similarly, remote students may need support remaining engaged, either directly from educators or through parents. Text messages to parents with weekly assignments and phone calls that describe learning activities in detail can stem the learning loss caused by school closures. (Angrist et al. 2020)

Policymakers must ensure that they do not fall victim to isomorphic mimicry; whereby they simply mimic other successful interventions, replicating their processes and systems without accounting for contextual constraints. This may give the impression that the intervention has been successful based on the fact that it worked elsewhere when in actual fact there hasn't been any tangible change.

According to Ganimian et al. (2020), policy makers should identify how the interactions among educators, learners and parents may be affected by the introduction of a new technology. This can then inform the implementation process (including the socialization of the program among key stakeholders) and help define a set of goals and objectives to measure progress and make course-corrections.

Further, if students are now expected to review the same content, without the structure and discipline provided in traditional classroom environments, alternative structures and incentives should be considered. Assuming students intend to fully engage with the content, minor behavioral "nudges" can be considered such as commitment devices (Patterson 2018), messages encouraging students not to procrastinate (Martinez 2014), or the use of planning tools and reminders (Yeomans and Reich 2017). Students could also be encouraged to commit to a regular study time or provided with tutoring services as part of the intervention (Banerjee and Duflo 2014). Another solution to consider is personalized feedback which enables students to compare their progress to that of their peers, as this has been shown to increase course completion rates and improve student achievement (Davis et al. 2017; Martinez 2013).

Some of these nudges have had mixed success in practice. For instance, nudges that encourage students to commit to engaging with distance learning content at particular times may fail because of a lack of a penalty if they fail to follow through with their commitment or because a "commitment device" may not be well suited to them (Baker et al. 2016).

If the intervention is likely to involve learners who fear being seen as less capable because of stereotyping, activities that reduce social identity threat could be integrated into the intervention. These could include a writing activity or reading testimonials from other learners from similar backgrounds with the aim of assuring learners that doubts about belonging in the course are normal and not unique to them (Kizilcec et al. 2017).

Table 3 provides a summary distance learning implementation pitfalls and potential solutions to overcome them. Note that these recommendations are predicated on the assumption that the product works effectively and uses the correct pedagogy.

Table 3: Distance Learning Implementation Pitfalls and Potential Solutions

CHALLENGE	DESCRIPTION	RECOMMENDATION
Infrastructure	There is insufficient infrastructure to support the distance learning intervention e.g., poor radio/TV broadcasting signal, unreliable electricity	Select distance learning solutions that are sufficiently supported by existing infrastructure
Technology access	There is insufficient access to technology at homes and in schools e.g., laptops/phones for distance learning interventions	If possible, provide students and teachers with technology that the distance learning intervention depends on
Teacher comfort with technology	Teachers are unfamiliar with the technology associated with the intervention	Train teachers how to use technology and provide additional support. Introduce a helpline teachers can call for assistance or have one person within the school who is well versed in the technology and can handle tech issues
Teacher motivation, compliance, and engagement	Teachers limit interactions with the distance learning intervention	Implement a monitoring system to track teacher engagement and provide teachers with incentives to engage with the intervention
Student motivation, compliance, and engagement	Students have limited interactions with course content resulting in poor course completion	Nudges such as text messages, commitment devices, reminders, and planning tools can encourage students to participate and complete their courses. Engaging parents to support learning activities can also help.

3.3 Step 3: Pilot, Monitor, and Iterate

Lastly, even the best quality programs might fail because of implementation challenges. As seen in Peru and Colombia, programs that simply assumed that teachers--once equipped and trained--would voluntarily incorporate the provided technology into their classrooms, did not lead to improved learning outcomes (Cristia et al. 2012; Barrera-Osorio et al. 2009). Mere training and equipment do not seem to be sufficient. For policymakers these lessons highlight the importance of monitoring implementation in three phases: piloting to understand the feasibility and possible efficacy of an intervention, evaluating the effectiveness at a larger scale, and once at scale, monitoring the main activities of the program.

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Appendix

5.1 Appendix A: Review Methodology and Data Collection

In reviewing and distilling the evidence, we chose to include only rigorous impact evaluations—sufficiently-powered experimental or quasi-experimental studies (with the addition of a few metanalyses that include non-experimental studies), which look at learning outcomes, and where authors discuss the program or theory in sufficient detail to understand how or why the program would improve learning outcomes.

This review draws from scholarly research publications, articles, and school ranking websites. The following sources were queried:[6]

- Google
- Google Scholar
- J-PAL, IPA, 3ie, and World Bank impact evaluation and systematic review repositories
- JSTOR
- Global education response trackers to CoVID-19

Eligible studies are those that:

- Evaluated a distance learning program that included at least one of the following categories of interventions: audio, video, computer, e-learning, internet, phone;

- Investigated programs that were designed for formal education or were targeted at learners of a typical learning age (e.g., young women and men aged between 5 and 35);

- Used experimental and quasi-experimental evaluations measuring impacts on eligible education outcomes;

- Had sample sizes large enough to detect impacts. We distinguish between small-sample studies that find large impacts and are statistically significant (which we include) and small-sample studies that fail to show statistically significant impacts, likely because they are underpowered (which we exclude); and

- Reported at least one eligible outcome variable measuring educational attainment (e.g., test scores, graduation, attendance).

We only included studies in English. Search results were reviewed, with relevant evidence and articles selected and examined in greater depth. We used the available literature to generate lessons and insights. We complemented these insights with evidence from high income countries that are relevant to the conceptual model.

5.2 Appendix B: Summary of Studies Included in the Distance Learning Evidence Review

PAPER DESCRIPTION	COUNTRY	PROGRAM TYPE (TECHNOLOGY)	SUBJECT	TARGET STUDENT	EVALUATION DESIGN	EFFECT SIZE	HIGH-LEVEL REASON FOR SUCCESS OR FAILURE
2.1.1 Supplement programs that increased learning							
Kwauk, Christina, Daniela Petrova, and Jenny P. Robinson. 2016. "Sesame Street: Combining Education and Entertainment to Bring Early Childhood Education to Children Around the World."	Global	Edutainment: Video (Television)	Literacy and numeracy, social and emotional development, health knowledge and practices, respect and understanding	Preschool students	Meta-analysis/ Literature review [N/A]	0.29 SD	**Contextualized:** Program tailored to country pedagogy, educational needs and goals of its children.
Borzekowski, Dina L.G., and Holly K. Henry. 2010. "The Impact of Jalan Sesama on the Educational and Healthy Development of Indonesian Preschool Children: An Experimental Study."	Indonesia	Edutainment: Video (Television)	Early cognitive skills, literacy, math, health and safety knowledge, social development, environmental awareness, cultural awareness	Preschool students	RCT [160 students 160 parents]	High-exposure: 0.35SD - Early cognitive skills 0.19SD - Number recognition 0.19SD - Counting	**Contextualized and Engaging:** Lessons were relatable, practical and applicable to children.
Borzekowski, Dina L. G., Agnes Lucy Lando, Sara H. Olsen, and Lauren Giffen. 2019. "The Impact of an Educational Media Intervention to Support Children's Early Learning in Rwanda."	Rwanda	Edutainment: Video (Television)	Letter identification, Numeracy, English vocabulary, Colour identification, Writing	Students aged 6 to 8 years old	Quasi-experimental (Difference in Differences) [402 students]	Not specified	**Contextualized and Engaging:** Lessons were relatable, practical and applicable to children.

PAPER DESCRIPTION	COUNTRY	PROGRAM TYPE (TECHNOLOGY)	SUBJECT	TARGET STUDENT	EVALUATION DESIGN	EFFECT SIZE	HIGH-LEVEL REASON FOR SUCCESS OR FAILURE
Baydar, Nazli, Çiğdem Kağitçibaği, Aylin C. Küntay, and Fatoğ Gökğen. 2008. "Effects of an Educational Television Program on Preschoolers: Variability in Benefits."	Turkey	Edutainment: Video (Television)	Family relations, Social development, Emotional development, Physical development (health), Environmental awareness, and Cognitive development	Students aged 4 to 6 years old without preschool experience	RCT [399 students]	Not specified	**Contextualized and Engaging:** Lessons were relatable, practical and applicable to children.
Lai, Fang, Linxiu Zhang, Qinghe Qu, Xiao Hu, Yaojiang Shi, Matthew Boswell, and Scott Rozelle. 2012. "Does Computer-Assisted Learning Improve Learning Outcomes? Evidence from a Randomized Experiment in Public Schools in Rural Minority Areas in Qinghai, China."	China	Computer Assisted Learning (Computer)	Mandarin	3rd grade students (aged 9 to 11) from underprivileged backgrounds	RCT [1,889 students 57 schools]	0.14 - 0.20 SD - Mandarin	**Quantity and Appropriate level:** Software was adaptive and could deliver content that matched each student's learning level as well as being relatable.
Muralidharan, Karthik, Abhijeet Singh, and Alejandro J. Ganimian. 2019. "Disrupting Education? Experimental Evidence on Technology-Aided Instruction in India."	India	Computer Assisted Learning (Computer)	Math and Hindi	6th to 9th grade students	RCT [619 students]	0.37 SD - Math 0.23SD - Hindi	**Appropriate level:** Program was adaptive and could deliver content that matched each student's learning level.

PAPER DESCRIPTION	COUNTRY	PROGRAM TYPE (TECHNOLOGY)	SUBJECT	TARGET STUDENT	EVALUATION DESIGN	EFFECT SIZE	HIGH-LEVEL REASON FOR SUCCESS OR FAILURE
Snipes, Jason, Chun-Wei Huang, Karina Jaquet, and Neal Finkelstein. 2015. "The effects of the Elevate Math summer program on math achievement and algebra readiness (REL 2015–096)."	USA	Computer Assisted Learning (Computer)	Algebra	8th grade students	RCT [477 students 8 schools]	0.68 SD - Mathematics Diagnostic Testing Project Algebra Readiness 0.53 SD - Algebra readiness	**Quantity:** Program increased learning time out-of-school reducing learning losses.
Singh, Ravi, Muhammad Saleem, Prabodha Pradhan, Cristina Heffernan, Neil T. Heffernan, Leena Razzaq, and Matthew D. Dailey. 2011. "Improving K-12 homework with computers."	USA	Computer Assisted Learning (Computer)	Math	8th grade students	RCT [172 students 2 teachers]	Math 0.4SD - Overall 0.54SD - Tutoring	**Incorporates Feedback, Engaging and Appropriate level:** Software was adaptive and could deliver content that matched each student's learning level, instant feedback provided and relatable to students.
Kelly, Kim, Neil Heffernan, Cristina Heffernan, Susan Goldman, James Pellegrino, and Deena Soffer Goldstein. 2013. "Estimating the Effect of Web-Based Homework."	USA	Computer Assisted Learning (Computer)	Math	7th grade students	RCT [63 students]	0.56 SD - Math	**Incorporates Feedback:** Students and teachers both provided feedback resulting in more informed reviews driven by data.

PAPER DESCRIPTION	COUNTRY	PROGRAM TYPE (TECHNOLOGY)	SUBJECT	TARGET STUDENT	EVALUATION DESIGN	EFFECT SIZE	HIGH-LEVEL REASON FOR SUCCESS OR FAILURE
Roschelle, Jeremy, Mingyu Feng, Robert F. Murphy, and Craig A. Mason. 2016. "Online Mathematics Homework Increases Student Achievement."	USA	Computer Assisted Learning (Computer)	Math	7th grade students	RCT [2,850 students]	0.18 SD - Math	**Incorporates Feedback, Appropriate level and Contextualized:** Software was adaptive, providing supplementary resources and delivering content that matched each student's learning level.
Foldnes, Njål. 2016 "The Flipped Classroom and Cooperative Learning: Evidence from a Randomised Experiment."	Norway	Computer Assisted Learning (Computer)	Statistics/Math	1st year undergraduate students	RCT [235 students]	12 percentage points	**Incorporates Feedback and Interactive:** team-based learning used with instant feedback from group members and instructor.
Wang, Haiwen, and Katrina Woodworth. August 2011. Evaluation of Rocketship Education's Use of DreamBox Learning's Online Mathematics Program."	USA	Computer Assisted Learning (Computer)	Math	Kindergarten and 1st grade students	RCT [583 students]	0.14 SD - Math	**Interactive and Engaging:** software resulted in increased interaction with content.

PAPER DESCRIPTION	COUNTRY	PROGRAM TYPE (TECHNOLOGY)	SUBJECT	TARGET STUDENT	EVALUATION DESIGN	EFFECT SIZE	HIGH-LEVEL REASON FOR SUCCESS OR FAILURE
Linden, Leigh. 2008. “Complement or Substitute? The Effect of Technology on Student Achievement in India.”	India	Computer Assisted Learning (Computer)	Math	3rd grade students	RCT [2,109 students]	-0.57 SD - Math as a substitute 0.28 SD - Math as a complement.	**Quantity:** Reduction in learning time as substitute to teachers with in-school model.
Lai, Fang, Linxiu Zhang, Xiao Hu, Qinghe Qu, Yaojiang Shi, Yajie Qiao, Matthew Boswell, and Scott Rozelle. 2013. “Computer Assisted Learning as Extracurricular Tutor? Evidence from a Randomised Experiment in Rural Boarding Schools in Shaanxi.”	China	Computer Assisted Learning (Computer)	Math	3rd and 5th grade students	RCT [2,613 students]	0.12SD - Math	**Appropriate level and Contextualised:** Software was adaptive and could deliver content that matched each student’s learning level as well as being relatable.
Lai, Fang, Renfu Luo, Linxiu Zhang, Xinzhe Huang, and Scott Rozelle. 2015. “Does Computer-Assisted Learning Improve Learning Outcomes? Evidence from a Randomized Experiment in Migrant Schools in Beijing.”	China	Computer Assisted Learning (Computer)	Math	3rd grade students	RCT [2,369 students]	0.15 SD - Math	**Appropriate level and Contextualised:** Software was adaptive and could deliver content that matched each student’s learning level as well as being relatable.

PAPER DESCRIPTION	COUNTRY	PROGRAM TYPE (TECHNOLOGY)	SUBJECT	TARGET STUDENT	EVALUATION DESIGN	EFFECT SIZE	HIGH-LEVEL REASON FOR SUCCESS OR FAILURE
Mo et al. (2015). Persistence of learning gains from computer assisted learning: Experimental evidence from China.	China	Computer Assisted Learning (Computer)	Math	3rd and 5th grade students	RCT [2,741 students 72 schools]	Math 0.25SD - 3rd grade students 0.26SD - 5th grade students	**Incorporates Feedback, Engaging and Appropriate level:** Software was adaptive and could deliver content that matched each student's learning level, instant feedback provided and relatable to students.
Riconscente, Michelle M. 2013. "Results From a Controlled Study of the IPad Fractions Game Motion Math."	USA	Computer Assisted Learning (Computer)	Math	5th grade students	Quasi-experimental (Difference in Differences) [122 students]	Fraction Knowledge 0.387 SD - Paper and timed 0.075 SD - iPad and not timed	**Incorporates Feedback, Engaging and Appropriate level:** Software was adaptive and could deliver content that matched each student's learning level, instant feedback provided and relatable to students.
Ragosta, Marjorie, 1982. "Computer-assisted Instruction and Compensatory Education: The ETS/ LAUSD Study."	USA	Computer Assisted Learning (Computer)	Math, Reading and Language	1st to 6th grade students	RCT [1,659 students]	0.15 - 0.45 SD - Reading and langauge arts (10-20 minutes) 0.25 SD - Math (10 min daily) 0.50 SD - Math (20 min daily)	**Appropriate level:** Software was adaptive and could deliver content that matched each student's learning level.

PAPER DESCRIPTION	COUNTRY	PROGRAM TYPE (TECHNOLOGY)	SUBJECT	TARGET STUDENT	EVALUATION DESIGN	EFFECT SIZE	HIGH-LEVEL REASON FOR SUCCESS OR FAILURE
Aker, Jenny C, Christopher Ksoll, and Travis J Lybbert. 2012. “Can Mobile Phones Improve Learning? Evidence from a Field Experiment in Niger.”	Niger	Mobile-based Intervention (Mobile Phone)	Literacy	Adult learners	RCT [6,700 adults 134 villages]	0.19 - 0.21 SD - Writing 0.25 SD - Math	**Engaging and Appropriate TLM:** Improved delivery of content by teachers.
Angrist, Noam, Peter Bergman, Caton Brewster, and Moitshepi Matsheng. 2020. “Stemming Learning Loss During the Pandemic: A Rapid Randomized Trial of a Low-Tech Intervention in Botswana.”	Botswana	Mobile-based Intervention: SMS and phone call (Mobile Phone)	Math	3rd to 5th grade students	RCT [4,550 students]	0.16 - 0.29 SD - Math	**Appropriate level and Interactive:** Increased parental engagement allowing for content to be delivered at a level that matched each student’s learning.
Angrist, Noam, Peter Bergman, and Moitshepi Matsheng. 2020. “School’s out: Experimental Evidence on Limiting Learning Loss Using “Low-Tech in a Pandemic.	Botswana	Mobile-based Intervention: SMS and phone call (Mobile Phone)	Math	3rd to 6th grade students	RCT [4,550 students]	0.12 - 0.17SD - Math	**Appropriate level and Interactive:** Increased parental engagement allowing for content to be delivered at a level that matched each student’s learning.

PAPER DESCRIPTION	COUNTRY	PROGRAM TYPE (TECHNOLOGY)	SUBJECT	TARGET STUDENT	EVALUATION DESIGN	EFFECT SIZE	HIGH-LEVEL REASON FOR SUCCESS OR FAILURE
Murat Saran and Gölge Seferoğlu. 2012. "Mobile Language Learning: Contribution of Multimedia Messages via Mobile Phones in Consolidating Vocabulary."	Turkey	Mobile-based intervention (Mobile Phone)	English	University students	Quasi-experimental (Difference in Differences) [103 students]	Not specified	**Appropriate TLM, Incorportates Feedback and Appropriate level:** Additional learning resources provided, instant feedback and content delivered that matched each student's learning level.
Suhr, Kurt A., David A. Hernandez, Doug Grimes, and Mark Warschauer. 2010. "Laptops and Fourth Grade Literacy: Assisting the Jump over the Fourth-Grade Slump	USA	Computer Access (Computer)	English Language Arts	4th and 5th grade students	Quasi-experimental (Difference in Differences) [108 students]	0.29SD - English language arts	**Inappropriate TLM:** Skills learned different from skills need to succeed in course.
2.1.2 Supplement programs that did not increase learning							
Leuven, Edwin, Mikael Lindahl, Hessel Oosterbeek, and Dinand Webbink. 2007. "The Effect of Extra Funding for Disadvantaged Pupils on Achievement."	Netherlands	Computer Access (Computer)	Language, Arithmetic, Information Processing, World Orientation	Primary school students from minority backgrounds	Quasi-experimental (Regression Discontinuity Design) [150,821 students 5,938 schools]	0.08SD (+/- 0.06SD) – Language 0.07SD (+/- 0.09SD) - Arithmetic	**Not Appropriate level:** Content not at level or in a relatable format to match the student's learning levels.

PAPER DESCRIPTION	COUNTRY	PROGRAM TYPE (TECHNOLOGY)	SUBJECT	TARGET STUDENT	EVALUATION DESIGN	EFFECT SIZE	HIGH-LEVEL REASON FOR SUCCESS OR FAILURE
Malamud, Ofer, and Cristian Pop-Eleches. 2011. "Home Computer Use and the Development of Human Capital."	Romania	Computer Access (Computer)	Math, Romanian and English	Students from underprivileged backgrounds	Quasi-experimental (Regression Discontinuity Design) [3,354 households]	0.33SD - Math, Romanian and English estimates clustered	**Inappropriate TLM:** No access to educational software.
Cristia, Julian, Pablo Ibarraran, Santiago Cueto, Ana Santiago, and Eugenio Severin. 2012. "Technology and Child Development: Evidence from the One Laptop Per Child Program."	Peru	Computer Access (Computer)	Math and Reading	Students aged 6 to 12 years old	RCT [319 schools]	No effects	**Poor Pedagogy:** No pedagogical model in place targeted toward increasing student achievement.
Fairlie, Robert W., and Jonathan Robinson. 2013. "Experimental Evidence on the Effects of Home Computers on Academic Achievement among Schoolchildren."	USA	Computer Access (Computer)	Math, English, Social Science, Science, and Computers	6th to 12th grade students	RCT [1,123 students]	No effects	**Quantity:** Zero net effect in time used for schoolwork.

PAPER DESCRIPTION	COUNTRY	PROGRAM TYPE (TECHNOLOGY)	SUBJECT	TARGET STUDENT	EVALUATION DESIGN	EFFECT SIZE	HIGH-LEVEL REASON FOR SUCCESS OR FAILURE
Faber, Benjamin, Rosa Sanchis-Guarner, and Felix Weinhardt. 2015. "ICT and Education: Evidence from Student Home Addresses."	United Kingdom	Internet Access (Internet)	English, Mathematics, Science	Primary and secondary school students	Quasi-experimental (Spatial regression discontinuity) [> 4.5 million students]	No effects	**Quantity:** Zero net effect in time used for schoolwork.
Piper, Benjamin, Stephanie Simmons Zuilkowski, Dunston Kwayumba, and Carmen Strigel. 2016. "Does Technology Improve Reading Outcomes? Comparing the Effectiveness and Cost-Effectiveness of ICT Interventions for Early Grade Reading in Kenya."	Kenya	Device Access: E-readers and tablets (E-readers and tablets)	English and Kiswahili	2nd grade students and teachers	RCT [80 schools]	With tablet: 0.29SD - English 0.32SD - Kiswahili With e-reader: 0.17SD - English 0.26SD - Kiswahili	**Appropriate TLM:** Necessary teaching and learning materials provided, along with pedagogy guidance.
Rouse, Cecilia E, and Alan B Krueger. 2004. "Putting Computerized Instruction to the Test: A Randomized Evaluation of a 'Scientifically Based' Reading Program."	USA	Computer Assisted Learning (Computer)	Reading Comprehension and Language	3rd to 6th grade students	RCT [512 students]	-0.24 - 0.31F - Language assessment -0.08 - 0.16F - Reading skills	**Not Interactive, Engaging and Contextualised:** Use not well defined, teacher not trained in technology use and hard to incorporate with current curriculum.

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Borman, G. B., Benson, J. G., & Overman, L. (2009). A Randomized Field Trial of the Fast ForWord Language Computer-Based Training Program.	USA	Computer Assisted Learning (Computer)	Literacy	2nd and 7th grade students	RCT [415 students 8 schools]	Language outcome 0.08SD - 2nd grade student Reading comprehension -0.07SD - 2nd grade student 0.21SD - 7th grade student	**Not Engaging, and Not Appropriate level:** Program repetitive, assignments of lower learning level.
Rutherford, Teomara, George Farkas, Greg Duncan, Margaret Burchinal, Melissa Kibrick, Jeneen Graham, Lindsey Richland, Natalie Tran, Stephanie Schneider, Lauren Duran and Michael E. Martinez. 2014. "A Randomized Trial of an Elementary School Mathematics Software Intervention: Spatial-Temporal Math."	USA	Computer Assisted Learning (Computer)	Math	3nd to 5th grade students	RCT [13,803 students]	0.07SD - Math	**Not Appropriate level:** Program not adaptable to student's learning needs.

PAPER DESCRIPTION	COUNTRY	PROGRAM TYPE (TECHNOLOGY)	SUBJECT	TARGET STUDENT	EVALUATION DESIGN	EFFECT SIZE	HIGH-LEVEL REASON FOR SUCCESS OR FAILURE
2.2.1 Substitute programs that increased learning							
Penuel, William R., Lauren Bates, Lawrence P. Gallagher, Shelley Pasnik, Carlin Llorente, Eve Townsend, Naomi Hupert, Ximena Domínguez, and Mieke VanderBorght. 2012. "Supplementing Literacy Instruction with a Media-Rich Intervention: Results of a Randomized Controlled Trial."	USA	Edutainment (Television)	Early childhood education: letter and sound recognition	Preschool students	RCT [436 children]	0.2 - 0.55SD -Recognition and sounding of letters and initial sounds of words	**Appropriate level, Interactive and Engaging:** Teachers able to guide engagement and content at the right learning level.
Wennersten, Matthew, Zubeeda Banu Quraishy, and Malathi Velamuri. 2015. "Improving Student Learning via Mobile Phone Video Content: Evidence from the BridgeIT India Project."	India	Mobile-based instructional videos (Mobile phone)	English and Science	5th and 6th grade students	Quasi-experimental (Matched, Difference in Differences) [3,327 students]	0.36SD - English 0.98SD - Science	**Engaging, Accurate delivery and Interactive:** Student-centered lessons.
Naslund-Hadley, Emma, Susan W. Parker, and Juan Manuel Hernandez-Agramonte. 2014. "Fostering early math comprehension: Experimental evidence from Paraguay."	Paraguay	Audio (Compact disk (CD))	Math	Preschool students	RCT [4,500 students]	0.16 SD - Math.	**Appropriate level:** Program delivered content at the right student learning level.

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Beg, Sabrin A., Adrienne M. Lucas, Waqas Halim, and Umar Saif. 2019. "Beyond the Basics: Improving Post-Primary Content Delivery through Classroom Technology."	Pakistan	Video (Tablet)	Math and Science	Middle school students	RCT [59 schools]	0.2-0.3 SD - Math and Science	**Appropriate level and Engaging:** Program delivered content at the right student learning level and was relatable for students.
Looi, Chee-Kit, Baohui Zhang, Weisha Chen, Peter Sen Kee Seow, G. Chia, Cathy Norris, and Elliot Soloway. 2011. "1:1 Mobile Inquiry Learning Experience for Primary Science Students: A Study of Learning Effectiveness."	Singapore	Mobile-based Intervention (Mobile phone)	Science	3rd grade students	Natural Experiment (Randomized) [359 students]	Not specified	**Appropriate level:** Program delivered content at the right student learning level.
Johnston, Jamie, and Christopher Ksoll. 2017. "Effectiveness of interactive satellite-transmitted instruction: Experimental evidence from Ghanaian primary schools."	Ghana	Interactive Television Instruction (Television)	Math and English	2nd to 5th grade students	RCT [147 schools]	0.23 SD - Math	**Accurate delivery:** Improvements in instructional practice.

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Mitchell, Mary Jane, and Barbara J. Fox. 2001. "The Effects of Computer Software for Developing Phonological Awareness in Lowğprogress Readers."	USA	Computer Assisted Learning (Computer)	Phonological awareness	Kindergarten and 1st grade students	RCT [72 students]	-0.61SD - Substitute 1.39SD - Supplement	**Quantity and Accurate delivery:** Improvements in instructional practice and more instructional time.
Banerjee, Abhijit, Shawn Cole, Esther Duflo, and Leigh Linden. 2007. "Remedying Education: Evidence from Two Randomized Experiments in India."	India	Computer Assisted Learning (Computer)	Math	4th grade students	RCT [175 schools]	Math 0.35SD - Year 1 0.47SD - Year 2	**Quantity and Accurate delivery:** Improvements in instructional practice and more instructional time.
Wijekumar, Kausalai Kay, Bonnie J. F. Meyer, and Puiwa Lei. 2012. "Large-Scale Randomized Controlled Trial with 4th Graders Using Intelligent Tutoring of the Structure Strategy to Improve Nonfiction Reading Comprehension."	USA	Computer Assisted Learning (Internet)	Reading comprehension	4th grade students	RCT [2,643 students 131 teachers 131 schools]	0.10SD - GSRT	**Accurate delivery:** Improvements in instructional practice.

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Wijekumar, Kausalai, Bonnie J. F. Meyer, Pui-Wa Lei, Yu-Chu Lin, Lori A. Johnson, James A. Spielvogel, Kathryn M. Shurmatz, Melissa Ray, and Michael Cook. 2014. "Multisite Randomized Controlled Trial Examining Intelligent Tutoring of Structure Strategy for Fifth-Grade Readers."	USA	Computer Assisted Learning (Internet)	Reading comprehension	5th grade students	RCT [128 classrooms 12 schools]	0.2 GSRT	**Incoporates Feedback and Accurate delivery:** Improvements in instructional practice and instant feedback on tasks.
Deault, Louise, Robert Savage, and Philip Abrami. 2009. "Inattention and response to the ABRACADABRA web-based literacy intervention."	Canada	Computer Assisted Learning (Internet)	Literacy	1st grade students	RCT [144 students]	0.26SD - Synthetic phonics 0.18SD - Analytic phonics	**Contextualized and Engaging:** Lessons were relatable, practical and applicable to children.
Barrow, Lisa, Lisa Markman, and Cecilia Elena Rouse. 2009. "Technology's Edge: The Educational Benefits of Computer-Aided Instruction."	USA	Computer Assisted Learning (Computer)	Math	Middle and high school students	RCT [59 teachers 141 classes 17 schools]	0.17SD - Pre algebra/ algebra	**Interactive and Engaging:** Individualised instruction.

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Morgan, Pat, and Steven Ritter. 2002. "An experimental study of the effects of Cognitive Tutor Algebra I on student knowledge and attitude."	USA	Computer Assisted Learning (Computer)	Math	Junior high students	RCT [1,048 students]	0.29SD - Math	**Appropriate level and Engaging:** Program delivered content at the right student learning level and was relatable for students.
Tatar, Deborah, Jeremy Roschelle, Jennifer Knudsen, Nicole Shechtman, Jim Kaput, and Bill Hopkins. 2008. "Scaling Up Innovative Technology-Based Mathematics."	USA	Computer Assisted Learning (Computer)	Math	7th grade students	RCT [25 teachers]	Not specified	**Contextualised and Accurate delivery:** Instruction provided in a variety of ways to ensure student's can learn more in short time frame.
Roschelle, Jeremy, Nicole Shechtman, Deborah Tatar, Stephen Hegedus, BillHopkins, Susan Empson, Jennifer Knudsen and Lawrence P. Gallagher. 2010. "Integration of Technology, Curriculum, and Professional Development for Advancing Middle School Mathematics: Three Large-Scale Studies"	USA	Computer Assisted Learning (Computer)	Math	7th and 8th grade students	RCT [1,621 - 7th grade students 825 - 8th grade students]	Math 0.63SD - Study 1 0.5SD - Study 2 0.56SD - Study 3	**Accurate delivery:** Improvements in instructional practice.

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Huizenga, Jantina, Wilfried Admiraal, Sanne Akkerman, and Geert Dam. 2009. "Mobile Game-Based Learning in Secondary Education: Engagement, Motivation and Learning in a Mobile City Game."	Netherlands	Computer Assisted Learning (Computer)	History	Students aged 12 to 16 years old	Quasi-experimental (Difference in Differences) [458 students]	Not specified	**Contextualized and Engaging:** Lessons were relatable, practical and applicable to children.
Hegedus, Stephen J., Sara Dalton, and John R. Tapper. 2015. "The Impact of Technology-Enhanced Curriculum on Learning Advanced Algebra in US High School Classrooms."	USA	Computer Assisted Learning (Computer)	Algebra	High school students aged 15 to 17 years	RCT and Quasi-experimental (Difference in Differences) [606 students (first year) 293 students (second year)]	Algebra 0.30SD - Year 1 0.18SD - Year 2	**Engaging, Accurate delivery and Interactive:** Student-centered lessons.
Pane, John F., Beth A. Griffin, Daniel F. McCaffrey, and Rita Karam. 2014. "Effectiveness of Cognitive Tutor Algebra I at Scale."	USA	Computer Assisted Learning (Computer)	Algebra	Middle and high school students in grades 6 to 12	RCT [18,700 students]	0.2 SD - Second year of implementing CTAI	**Accurate delivery:** Improvements in instructional practice.

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Zhang, Dongsong. 2005 "Interactive Multimedia-Based E-Learning: A Study of Effectiveness."	USA	E-learning (Computer)	Algebra; Management Information Systems	Undergraduate students	RCT [155 students]	Algebra 0.766SD - Fully Interactive 0.271SD - Less interactive	**Appropriate TLM, Interactive and Incorporates Feedback:** Necessary learner materials provided and instant feedback when questions asked.
Zhang, Dongsong, Lina Zhou, Robert O. Briggs, and Jay F. Nunamaker Jr. 2006. "Instructional Video in e-learning: Assessing the Impact of Interactive Video on Learning Effectiveness."	USA	E-learning (Computer)	Management Information Systems	Undergraduate students	RCT [138 students]	Not specified	**Interactive and Engaging:** Student's found program captivating and relatable.
Eden, Sigal, Adina Shamir, and Maayan Fershtman. 2011. "The Effect of Using Laptops on the Spelling Skills of Students with Learning Disabilities."	Israel	Computer Access (Computer)	Computer Literacy, Spelling	Students in 7th to 9th grade with learning disabilities who attend special education classes	Quasi-experimental (Difference in Difference) [93 students]	0.29SD	**Interactive and Engaging:** Student's found program captivating and relatable.

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2.2.2 Substitute programs that did not increase learning							
Linden, Leigh. 2008. "Complement or Substitute? The Effect of Technology on Student Achievement in India."	India	Computer Assisted Learning	Math and Language	2nd and 3rd grade students	RCT [2,109 students 60 schools]	Math -0.57 SD - Substitute 0.28 SD - Complement.	**Contextualised:** Poor substitute but good supplement.
Bowen, William G., Matthew M. Chingos, Kelly A. Lack, and Thomas I. Nygren. 2012. "Interactive Learning Online at Public Universities: Evidence from a Six-Campus Randomized Trial."	USA	E-learning (Computer)	Statistics	Undergraduate students	RCT [605 students]	Not specified	**Accurate delivery and interactive:** Improvements in instructional practice and more relatable to students'.
Cabalo, Jessica Villaruz, Andrew P. Jaciw, and Minh-Thien Vu. 2007. "Comparative Effectiveness of Carnegie Learning's" Cognitive Tutor" Algebra I Curriculum: A Report of a Randomized Experiment in the Maui School District. Research Report."	USA	Computer Assisted Learning (Computer)	Algebra	8th to 13th grade students	RCT [541 students]	0.03SD - Algebra	**Inappropriate TLM:** Unfavourable resources for implementation.

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Ferman, Bruno, Lucas Finamor, and Lycia Lima. 2019. "Are Schools Ready to Integrate Math Classes with Khan Academy?"	Brazil	E-learning (Computer)	Math	5th and 9th grade students	RCT [157 schools]	0.06SD - Average, 0.062SD - 5th grade, 0.057 SD - 9th grade	**Interactive and Engaging:** Student's found program captivating and relatable.
Barrera-Osorio, Felipe, and Leigh Linden. 2009. "The Use and Misuse of Computers in Education: Evidence from a Randomized Experiment in Colombia."	Colombia	Computer Access (Computer)	Math and Spanish	1st to 9th grade students	RCT [8216 students 97 schools]	<-0.1SD - Math < -0.1SD - Spanish	**Inaccurate delivery:** teachers failed to implement the technology despite training and technical support.
Pane, John F., Daniel F. McCaffrey, Jennifer L. Steele, Gina S. Ikemoto, and Mary Ellen Slaughter. 2010. "An experiment to evaluate the efficacy of cognitive tutor geometry."	USA	Computer Assisted Learning (Computer)	Math	High school students	RCT [699 students]	-019SD - Math	**Inaccurate delivery:** teachers unfamiliar with learner-centric focus with classroom activities.
Cavalluzzo, Linda, Deborah L. Lowther, Christine Mokher, and Xitao Fan. 2012. "Effects of the Kentucky Virtual Schools' Hybrid Program for Algebra I on Grade 9 Student Math Achievement".	USA	E-learning (Computer)	Algebra	9th grade students	RCT [6,908 students 47 schools]	-0.15SD -Pre algebra/ algebra	**Inaccurate delivery:** teachers failed to implement the technolgy despite training and technical support.

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Joyce, Theodore J, Sean Crockett, David A Jaeger, Onur Altindag, and Stephen D O'Connell. 2014. "Does Classroom Time Matter? A Randomized Field Experiment of Hybrid and Traditional Lecture Formats in Economics."	USA	E-learning (Computer and Internet)	Microeconomics	Undergraduate students	RCT [725 students]	Not specified	**Quantity:** Reduced quantity of learning time at expense of performance.
Smith, Jeanne. 1983. "Evaluation of the Telecourse Program at Saddleback College: Student Retention and Academic Achievement."	USA	Video (Television)	Political Science, Psychology, Music, Marine Science	Undergraduate students	Quasi-experimental (Synthetic Control) [205 students]	Not specified	**Inaccurate delivery:** Poor implementation of orientation activities.
Figlio, David N., Mark Rush, and Lu Yin. 2010. "Is It Live or Is It Internet? Experimental Estimates of the Effects of Online Instruction on Student Learning."	USA	E-learning (Computer and Internet)	Microeconomics	Undergraduate students	RCT [327 students]	Not specified	**Quantity:** Students interacted less with material and instruction in virtual method.
Brown, Byron W., and Carl E. Liedholm. 2002. "Can web courses replace the classroom in principles of microeconomics?."	USA	E-learning (Computer and Internet)	Microeconomics	Undergraduate students	RCT [710 students]	Not specified	**Quantity:** Students interacted less with material and instruction in virtual method.

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Alpert, William T., Kenneth A. Couch, and Oskar R. Harmon. 2016. "A Randomized Assessment of Online Learning."	USA	E-learning (Computer and Internet)	Microeconomics	Undergraduate students	RCT [803 students]	Not specified	**Poor Pedagogy:** No pedagogical model in place targeted toward increasing student achievement.
Powell, Cynthia B., and Diana S. Mason. 2013. "Effectiveness of Podcasts Delivered on Mobile Devices as a Support for Student Learning During General Chemistry Laboratories."	USA	Audio and video (iPhone and iPod)	Chemistry	Undergraduate students	RCT [132 students]	0.18SD - Chemistry	**Accurate delivery:** instructional quality maintained.
Recommendations							
Ganimian, Alejandro J., Emiliana Vegas, and Fredrick M. Hess. 2020. "Realizing the promise: How can education technology improve learning for all?"	Global	N/A	Metaanalysis [N/A]	N/A	N/A	N/A	N/A
Patterson, Richard W. 2018. "Can Behavioral Tools Improve Online Student Outcomes? Experimental Evidence from a Massive Open Online Course."	Global	E-learning (Computer and Internet)	Statistics	The course was a MOOC course that was open to anyone worldwide	RCT [657 students]		**Social and Emotional:** Nudges effective in getting students to do desired action.

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Recommendations							
Martinez, Ignacio. 2014. "Never Put Off Till Tomorrow?"	Global	E-learning (Computer and Internet)	Foundations of Business Strategy	The course was a MOOC course that was open to anyone worldwide	RCT and Quasi-experimental (Instrumental Variable) [24,122 students]		**Social and Emotional:** Nudges effective in getting students to do desired action.
Banerjee, Abhijit and Esther Duflo. 2014. "Structured Study Time, Self-Efficacy, and Tutoring."	Global	E-learning (Computer and Internet)	Development Economics	The course was a MOOC course that was open to anyone worldwide	RCT [19,694 students]		
Yeomans, Michael, and Justin Reich. 2017. "Planning Prompts Increase and Forecast Course Completion in Massive Open Online Courses."	Global	E-learning (Computer and Internet)	Business, Chemistry, and Political Science	The course was a MOOC course that was open to anyone worldwide	RCT [2,053 students]		**Social and Emotional:** Nudges effective in getting students to do desired action.
Davis, Dan, Ioana Jivet, René F. Kizilcec, Guanliang Chen, Claudia Hauff, and Geert-Jan Houben. 2017. "Follow the Successful Crowd: Raising MOOC Completion Rates through Social Comparison at Scale."	Global	E-learning (Computer and Internet)	Calculus, Business, Drinking Water Treatment, Urban Sewage Treatment	The course was a MOOC course that was open to anyone worldwide	RCT [33,726 students]		**Incorporates Feedback:** Instant feedback provided to learners.

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Recommendations							
Martinez, Ignacio. 2013. "The Effects of Nudges on Students' Effort and Performance: Lessons From a MOOC."	Global	E-learning (Computer and Internet)	Business	The course was a MOOC course that was open to anyone worldwide	RCT [7,924 students]		**Social and Emotional:** Nudges ineffective in getting students to do desired action.
Baker, Rachel, Brent Evans, and Thomas Dee. 2016. "A Randomized Experiment Testing the Efficacy of a Scheduling Nudge in a Massive Open Online Course (MOOC)."	Global	E-learning (Computer and Internet)	Science	The course was a MOOC course that was open to anyone worldwide	RCT [18,043 students]		**Social and Emotional:** Nudges ineffective in getting students to do desired action.


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