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1. Introduction

Over the past two decades, low- and middle-income countries have made great progress in expanding access to schooling—especially to children and youth from the most disadvantaged families (UNESCO, 2019). Yet, this expansion has brought an influx of new students to schools with widely varying levels of preparation; many of whom have parents with little or no experience with school (Pritchett & Beatty, 2015). Thus, the frontier challenge in these settings has become to reform school management and classroom instruction (which have traditionally focused on "screening" elites for higher education and the labor market) to ensure minimum levels of learning for all students. To meet this challenge, school systems need not only to change incentive structures, which often encourage teachers to focus on the top of the ability distribution, but also to build capacity within the system to cater to the diverse needs of the most disadvantaged students (see Banerjee et al., 2017; Banerjee & Duflo, 2011).

Education technology, or "ed-tech," refers to the introduction of information and technology tools in teaching and learning. Ed-tech has long been heralded as a potentially game-changing "disruption" for school systems (see, for example, Christensen, Horn, & Johnson, 2011). This is in part because of its comparative advantages, relative to traditional "chalk-and-talk" classroom instruction. It can, among other things, scale up standardized instruction, facilitate differentiated instruction, expand opportunities for practice, and increase student engagement (see, e.g., Banerjee, Cole, Duflo, & Linden, 2007; Muralidharan, Singh, & Ganimian, 2019). Recent advances in artificial intelligence and machine learning, and the novel coronavirus, which caused school closings affecting over 1.5 billion students worldwide, have only intensified calls for increased use of technology in education (see, e.g., Marcus, 2020; Ovide, 2020; Weise, 2020).

However, in spite of the relentless optimism that has characterized the movement for education technology, its results have been mostly disappointing (for reviews, see Bulman & Fairlie, 2016; Escueta, Nickow, Oreopoulos, & Quan, forthcoming; Tauson & Stannard, 2018). Most notably, evidence from randomized experiments, which are designed to estimate the causal effect of programs and policies, suggests that merely equipping a school or a student with hardware (e.g., tablets, laptops, or desktop computers) has had little effect on student learning—and, in some cases, has distracted students from schoolwork (see, e.g., Barrera-Osorio & Linden, 2009; Beuermann, Cristia, Cruz-Aguayo, Cueto, & Malamud, 2015; Cristia, Ibarrarán, Cueto, Santiago, & Severín, 2017; Malamud & Pop-Eleches, 2011). Educational software that allows students to practice what they learned at school has been slightly more successful, but it has largely had modest effects (see, e.g., Huang et al., 2014;

Lai et al., 2012; Mo et al., 2015). In short, the potential of education technology has not yet been realized.

In this report, we argue for a simple yet surprisingly rare approach to education technology that seeks to: (a) understand the needs, infrastructure, and capacity of a school system; (b) survey the best available evidence on interventions that match those conditions; and (c) closely monitor the results of innovations before they are scaled up. We believe this approach is sorely needed in the "ed-tech" space, where governments have often favored popular over effective reforms. The multiplicity of hardware and software products—and the eagerness in their promotion—makes it challenging for well-intended but time-constrained public officials to understand the extent to which they can improve learning. A unifying theme throughout this report is that those interested in realizing the potential of education technology should think carefully about how it will improve the learning process.

The report is structured as follows. Section 2 adapts a framework to think about the potential levers of system improvement—specifically, the interactions between teachers, students, and the instructional material, and how they can be mediated through parents. Section 3 proposes an approach to diagnose the needs, infrastructure, and capacity of a school system to adopt ed-tech interventions. Section 4 provides an overview of the four potential comparative advantages of technology to improve learning outcomes, and reviews the most rigorous evidence available on interventions from developing countries. Finally, section 5 outlines how school systems can monitor the results of innovations to understand how well they are implemented and whether they are delivering the desired improvements in student learning.

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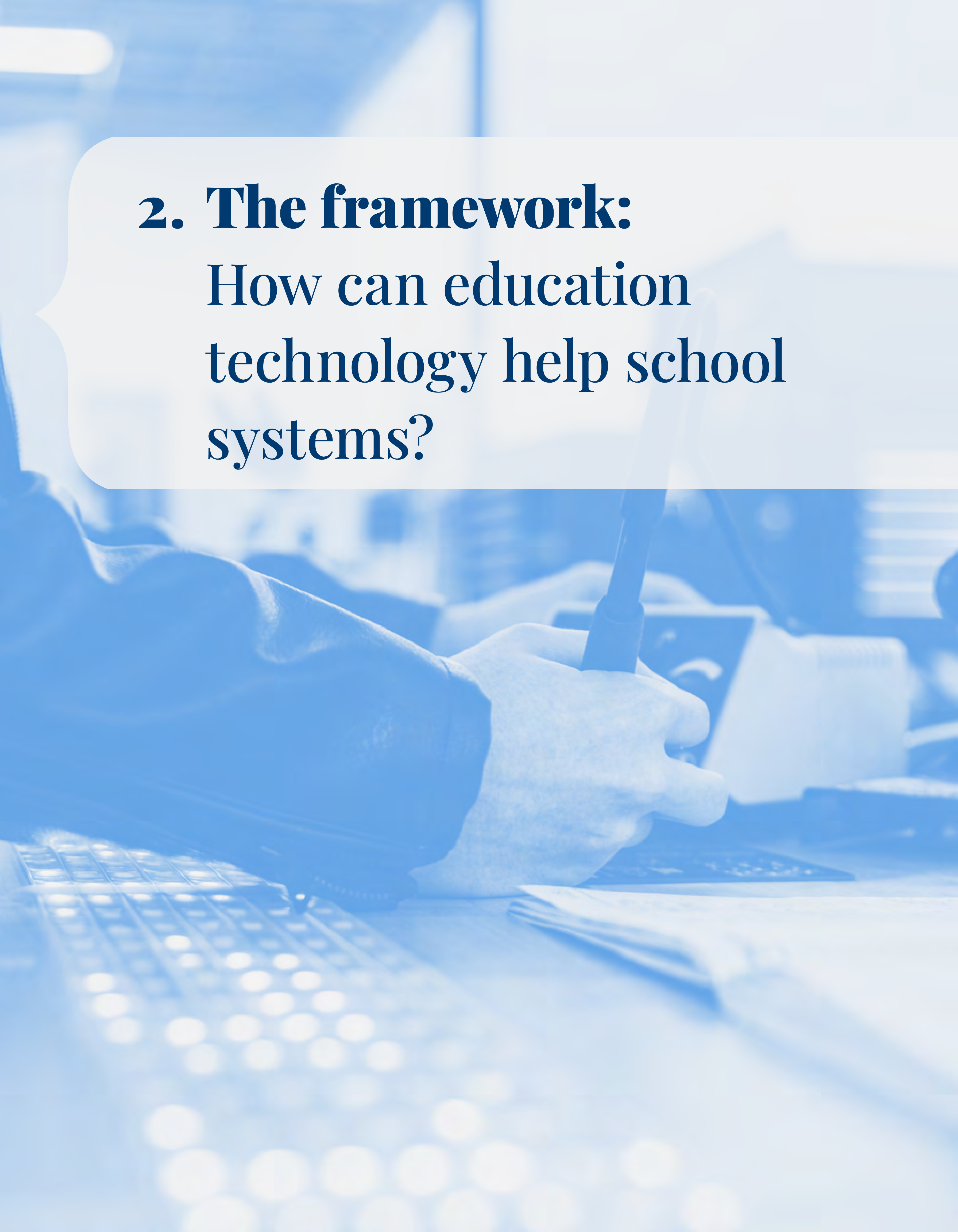
2. The framework: How can education technology help school systems?

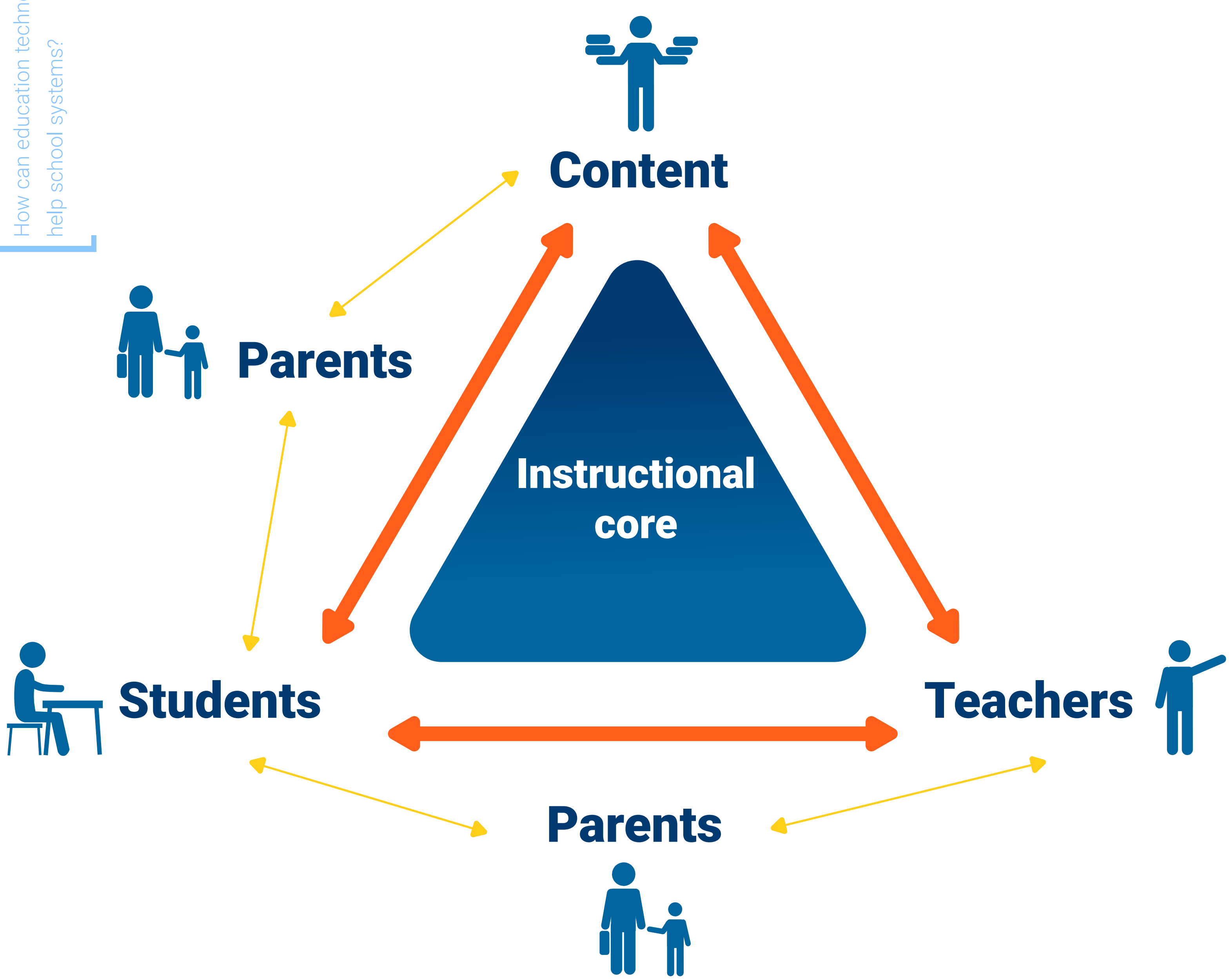


Two decades ago, two of the most prominent education researchers in the United States, David K. Cohen and Deborah Loewenberg Ball, noted a disturbing trend in education reform: In spite of good intentions, a great number of school-improvement efforts had either failed or been unable to sustain their success over time. They argued that previous initiatives had paid insufficient attention to teaching and learning, and to guide future reform efforts, they put forth a simple yet intuitive theoretical framework to think about levers of improvement that has had remarkable staying power (see, e.g., Kane & Staiger, 2012).

In their framework, Cohen and Ball (1999) argue that what matters most to improve learning is the *interactions* among teachers and students around educational materials. They developed a model that represents instruction (and efforts to improve it) as a triangle in which each vertex represents students, teachers, and content—which can be delivered through traditional and/or technology-enabled instruction (see Figure 1: The Instructional core). The two-sided arrows connecting the vertices indicate that it is the interactions among these three elements—rather than any one of them—that results in learning, and that a change in one element affects all others (e.g., higher quality materials will enable teachers to improve instruction and students to understand the material). They dubbed the center of all three of these elements the "instructional core."

We believe that the failed school-improvement efforts in the U.S. that motivated Cohen and Ball's framework resemble the ed-tech reforms in much of the developing world to date in the lack of clarity improving the interactions between teachers, students, and the educational material—or what Murnane and Willett (2011) have called "children's daily experiences in school" in pre-pandemic times. Consequently, we posit that there is much to learn from this model to redirect current debates among policymakers and practitioners on using technology to improve learning. We build on the Cohen and Ball framework by adding parents as key agents that mediate the relationships between students and teachers and the material (especially during the pandemic).

Figure 1:
The Instructional core

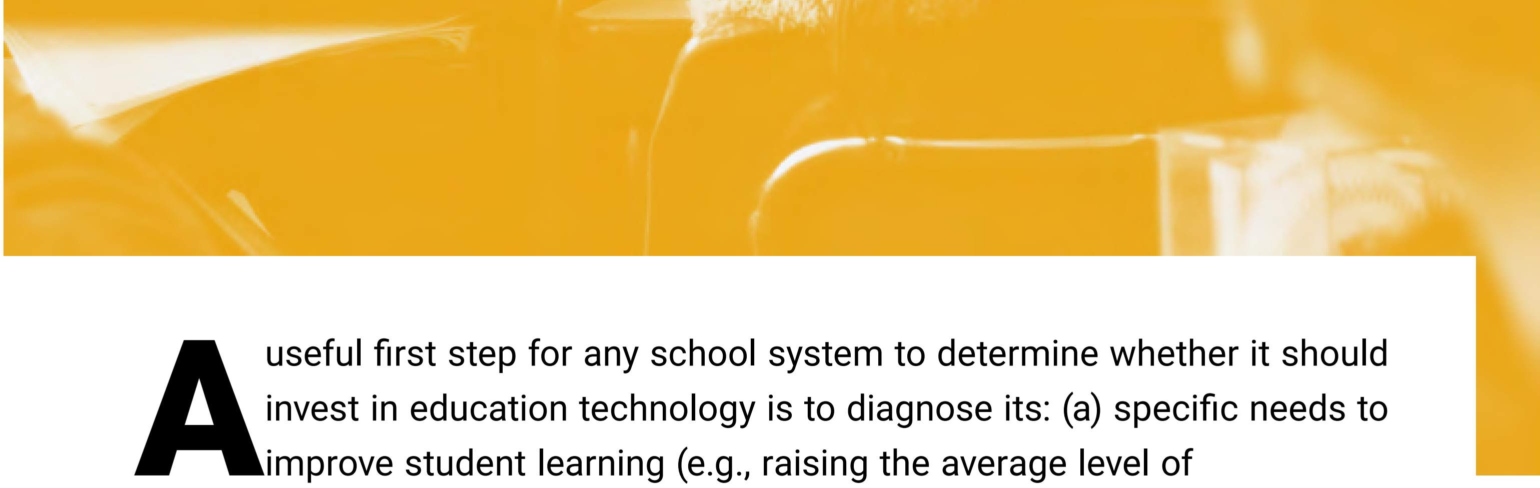


Adapted from Cohen and Ball (1999).

As the figure above suggests, ed-tech interventions can affect the instructional core in a myriad of ways. They may improve the quality of the content students access (e.g., through online videos, either self-paced or under parental supervision) and the teachers who use them (e.g., through prerecorded or live lessons). They may also change the way that teachers access learning resources (e.g., through repositories of lesson plans and activities) and how they engage with students (e.g., directly, through learning management systems, or indirectly, through text messages with their parents).

Yet, just because technology *can* do something, it does not mean it *should*. School systems in developing countries differ along many dimensions, including their size, level and distribution of students' skills, and the capacity of its public-sector bureaucracy to implement reforms at scale and of teachers to deliver high-quality instruction (see, e.g., Andrews, Pritchett, & Woolcock, 2017; Pritchett, 2013). Therefore, each system is likely to have different needs for ed-tech interventions, as well as different infrastructure and capacity to enact such interventions. This is why we recommend that governments interested in adopting ed-tech interventions begin by taking stock of their initial conditions. This is the focus of the next section.

3. The diagnosis: How can school systems assess their needs and preparedness?



A useful first step for any school system to determine whether it should invest in education technology is to diagnose its: (a) specific needs to improve student learning (e.g., raising the average level of achievement, remediating gaps among low performers, and challenging high performers to develop higher-order skills); (b) infrastructure to adopt technology-enabled solutions (e.g., electricity connection, availability of space and outlets, stock of computers, and Internet connectivity at school and at students' homes); and (c) capacity to integrate technology in the instructional process (e.g., students' and teachers' level of familiarity and comfort with hardware and software, their beliefs about the level of usefulness of technology for learning purposes, and their current uses of such technology).

Before engaging in any new data collection exercise, school systems should take full advantage of existing administrative data that could shed light on these three main questions. Many developing countries already engage in a regular census of schools and staff that could provide considerable information on basic questions such as schools' infrastructure conditions. Others conduct periodic assessments of student learning that are often accompanied by background questionnaires that can provide useful information on the extent to which students, teachers, and school leaders are already using technology for education, what they need to make greater use of it (e.g., resources and/or training), and the extent to which they are amenable to such utilization. Yet, other developing countries also participate in international student assessments, such as the Program for International Student Assessment (PISA), the Trends in International Mathematics and Science Study (TIMSS), and/or the Progress in International Literacy Study (PIRLS), and the Teaching and Learning International Study (TALIS), which already collect a wealth of information for primary and secondary education. Given the time and costs involved in data collection, it is imperative that school systems take full advantage of these data.

Whether school systems lack information on their preparedness for ed-tech reforms and/or if they seek to complement the data that they have with a richer set of indicators, we developed a set of surveys for students, teachers, and school leaders in Appendix A.[1] We have drawn extensively on previous efforts such as the surveys from PISA (OECD, 2005, 2019), TIMSS (Mullis, Martin, Foy, & Hooper, 2016), PIRLS (IEA, 2015), and TALIS (OECD, 2014). Our surveys focuses on grade 10 students, for two reasons: (a) This is the age around which most prior surveys have been conducted, allowing for comparisons to previous efforts; and (b) This is the age at which students can be reasonably expected to have had some exposure to education technology, both for schoolwork and for preparation for the labor force. However, the surveys are also relevant and may be adapted for students in other grades in elementary and secondary schools. Below, we map out the main aspects covered by these surveys, in hopes of highlighting how they could be used to inform decisions around the adoption of ed-tech interventions.

1 The Center for Universal Education at Brookings is developing a separate playbook focusing on engaging parents in innovations to accelerate student learning and will include sample survey instruments.

Identifying the key challenges to improve student learning

The first type of information that would be useful for the leaders of a school system before adopting an ed-tech intervention is identifying its main student-learning challenges. The first part of this process involves understanding the subset of the student achievement distribution it is trying to target and the purpose for doing so. For example, some systems with very low levels of achievement across the board are primarily concerned with ensuring that all

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students reach minimum standards, others with a long “left tail” are chiefly preoccupied with helping the lowest-performing students catch up with their peers, and yet others with few high-achieving students are looking for ways to encourage them to acquire higher-order skills. For example, to ensure minimum levels of learning, a school system may want to: experiment with delivering standardized content using prerecorded lessons; integrate computer-adaptive software into regular lessons to help low performers catch up; and adopt technology-enabled competitions to motivate higher achievers (e.g., math Olympics). A system may want to achieve all of these three goals at once, but this first step reminds leaders that each of these objectives will likely require different types of solutions, and that the more solutions are attempted, the more challenging their simultaneous implementation will be.

The second part of this process entails understanding the extent to which the school systems are already succeeding in addressing the aforementioned problems. For example, in some systems, all or nearly all schools may be struggling to improve learning, while in others, some groups of schools may already be succeeding through traditional instruction. This step matters for two main reasons. First, it will help decisionmakers determine where to substitute regular instruction and where it should be complemented. For example, an impact evaluation in a network of well-functioning private schools in India, which we review in greater detail below, found that a remedial software program negatively impacted students' achievement—probably because regular

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instruction was already of high enough quality (Linden, 2008). Conversely, an impact evaluation of similar software in public schools in Delhi suggested that it should be incorporated into the school day—in great part, because lower-performing children made almost no academic progress during the school year (Muralidharan, Singh, et al., 2019). Second, this step will also help decisionmakers assess whether to amplify the impact of highly effective schools and or teachers (e.g., through prerecorded or live lessons from central locations) instead of creating new material from scratch (see, e.g., Beg, Lucas, Halim, & Saif, 2020; de Barros, 2020, also reviewed below).

A great deal of information on these questions likely already exists (e.g., from domestic or international student assessments). However, student and teacher surveys can provide important complementary information. For example, student surveys could shed light on their self-efficacy levels across different subjects and/or topics within those subjects, whereas teacher surveys could yield valuable insights into the subjects and/or topics where teachers need further support (e.g., due to gaps in their training and/or persistence of low student achievement). More generally, students and teachers are far more likely to seek extra help in areas in which they perceive themselves as needing support, so even if surveys merely confirm the results of large-scale assessments, they may serve to build consensus around targeted foci of improvement. To this end, we have included a number of questions assessing students' and teachers' self-efficacy in specific skills (which may be adjusted to focus on particular subjects), the activities they are currently undertaking to develop such skills, and their demand for additional supports.

Taking stock of ed-tech infrastructure

A natural next step for those interested in adopting ed-tech interventions is to take stock of the available infrastructure in schools (and ideally, also at students' homes) to deploy them. This may seem obvious, and almost not worth mentioning, but a well-documented reason why free laptop provision programs failed in many developing countries is because schools and homes either lacked Internet connectivity or had intermittent access to it (Robertson, 2018). Taking stock of available infrastructure is crucial not just to dissuade decisionmakers from pursuing ed-tech interventions that require unrealistic upgrades in current infrastructure (either in terms of funding or time), but also to identify the optimal delivery mechanism. For example, free text-messaging systems (e.g., WhatsApp) have rapidly become ubiquitous in developing countries as a means of communication among teachers and between school leaders and parents. Yet, for the most part, ed-tech interventions have relied on more traditional technology (e.g., short-message systems or SMS). This stock-taking exercise is not just about what is missing; it is also about what is already there, so that it can be leveraged to improve student learning.

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The first and most basic part of this process is to document the available physical infrastructure at school (e.g., number of classrooms and availability of computer rooms) and at students' homes (e.g., availability of space for students to study). For example, if schools already have extra- or multi-use rooms that can be repurposed for learning purposes, or space resulting from consolidations, it might make sense to implement interventions there. Conversely, if students have space at home or community-based organizations (e.g., local libraries), it might make sense to deploy interventions before or after school hours. Physical infrastructure, however, is not just about classrooms; it also includes other aspects, such as the availability of electricity, wiring, and outlets for devices. These seemingly minor details have constrained the scale up of otherwise effective ed-tech interventions (see, e.g., Muralidharan & Singh, 2019). Principals are best positioned to report on their schools' overall infrastructure, but teachers can complement their reports by indicating infrastructure-related constraints to ed-tech implementation in their own classrooms. Students, if they are old enough, may be able to report on their resources at home and in their community.

The second and related part of this process entails documenting the extent to which students have access to hardware (e.g., desktop computers, laptops, netbooks, tablets, or cell phones) at home or at school. This includes not only noting the number of available pieces of hardware in both settings, but also the extent to which they are functional and available for use. One of the reasons why ed-tech materials have had surprisingly little impact on student learning is

because they are kept from students for fear that they will be broken or stolen, and that supervisors will discover this (see, e.g., Sabarwal, Evans, & Marshak, 2014). Anecdotal evidence suggests that this also occurs with hardware equipment meant to be used by students, such as laptops and netbooks. Thus, while it is useful to ask principals and teachers about the availability of such resources in their schools and classrooms, it is also important to check that students can use them. If school officials are keeping this equipment from children for fear of not receiving these resources in the future, no amount of funds spent on education technology will improve learning.

Again, a great deal of this information is already periodically collected in many developing countries, either through census of schools and staffing, or through civil-society organizations in defense of the right to education (see, e.g., ASER, 2019). Governments should leverage these efforts to identify geographic areas and schools in severe need of upgrading. Doing so will also allow governments to be much more strategic about where to collect data to verify insufficient infrastructure and to investigate those areas in greater detail. Whenever possible, governments should identify the main barriers to appropriate utilization of infrastructure and equipment that addresses schools' limiting of children's access to the educational material they need to learn.

Assessing capacity to integrate technology in the learning process

The last important step in this diagnostic exercise is to assess the degree to which school leaders, teachers, and students are ready, willing, and able to integrate technology into the learning process. This may seem simpler than it actually is. Given the increasing role that technology plays in our daily lives, which cuts across socio-economic strata, it may appear inevitable that all actors in the school system will eventually welcome it into the classroom. Yet, school leaders, teachers, and student may actually have legitimate reasons to resist it. For example, some principals may have to make non-trivial changes to existing timetables, which in many contexts are carefully designed around teachers' availability. Some teachers may lack the requisite knowledge to deploy technologies and may not have access to adequate training or to on-site support for troubleshooting. Students may value one-on-one interactions with teachers and peers or may fear that availability of technological resources at home, which is highly correlated with family income, may offer an unfair advantage to their wealthier peers. In assessing capacity for ed-tech

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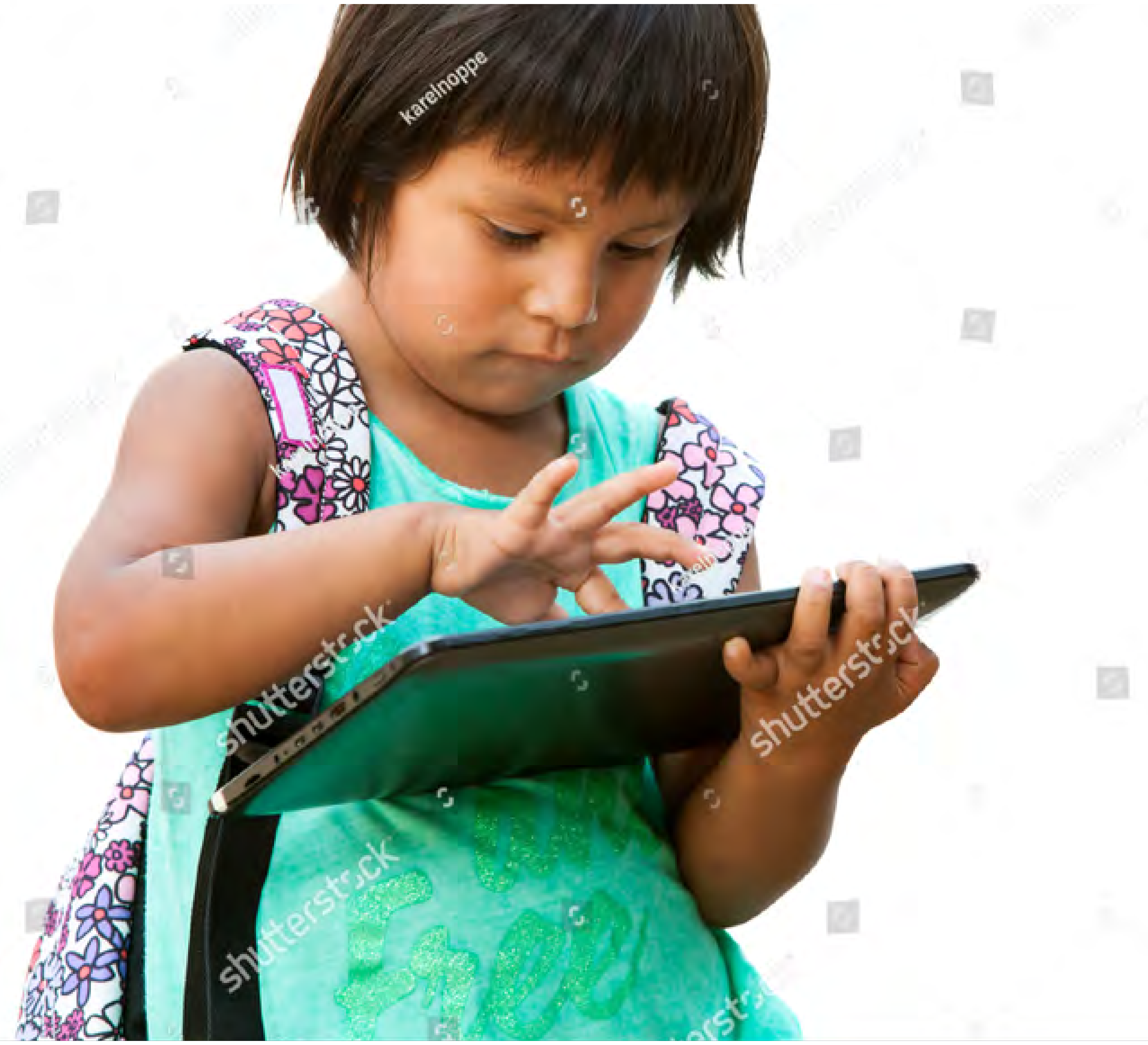
deployment, perhaps the most important aspect is to listen and carefully evaluate the concerns of skeptics and detractors, rather than to dismiss them as standing in the way of the inevitable. Many of those concerns may raise flags about potential behavioral challenges for take-up that can be addressed through the interventions themselves (e.g., by providing adequate training) and predict where trying to press ahead may generate cynicism and resistance to other reforms.

The first part of this stage, and perhaps the easiest, is to assess the technical skills of chiefly teachers and students. Some of this information can be directly obtained or inferred from international assessments, such as the International Computer and Information Literacy Study (ICILS) (Fraillon, Ainley, Schultz, Friedman, & Duckworth, 2020); from the computer-based administration of large-scale assessments, such as PISA (OECD, 2019); or from similar exercises at the national or sub-national level. However, to this day, participation in these types of surveys remains low among developing countries. A different, but complementary, approach is simply asking principals, teachers, and students about their level of familiarity with varying types of hardware or software frequently used for learning purposes (e.g., word-processing software or spreadsheets), their self-assessed level of comfort engaging in basic tasks (e.g., saving files, browsing the Internet), and/or the frequency with which they use technology for different learning-related purposes (e.g., reading news stories, preparing budgets, etc.) None of these measures are failproof; they tend to be susceptible to overly optimistic answers because all of us struggle to be accurate or objective when assessing our own skills and because the questions themselves may be consciously or unconsciously interpreted as expectations. Yet, they may offer a sense of the subjective perceptions of readiness for embracing ed-tech interventions.

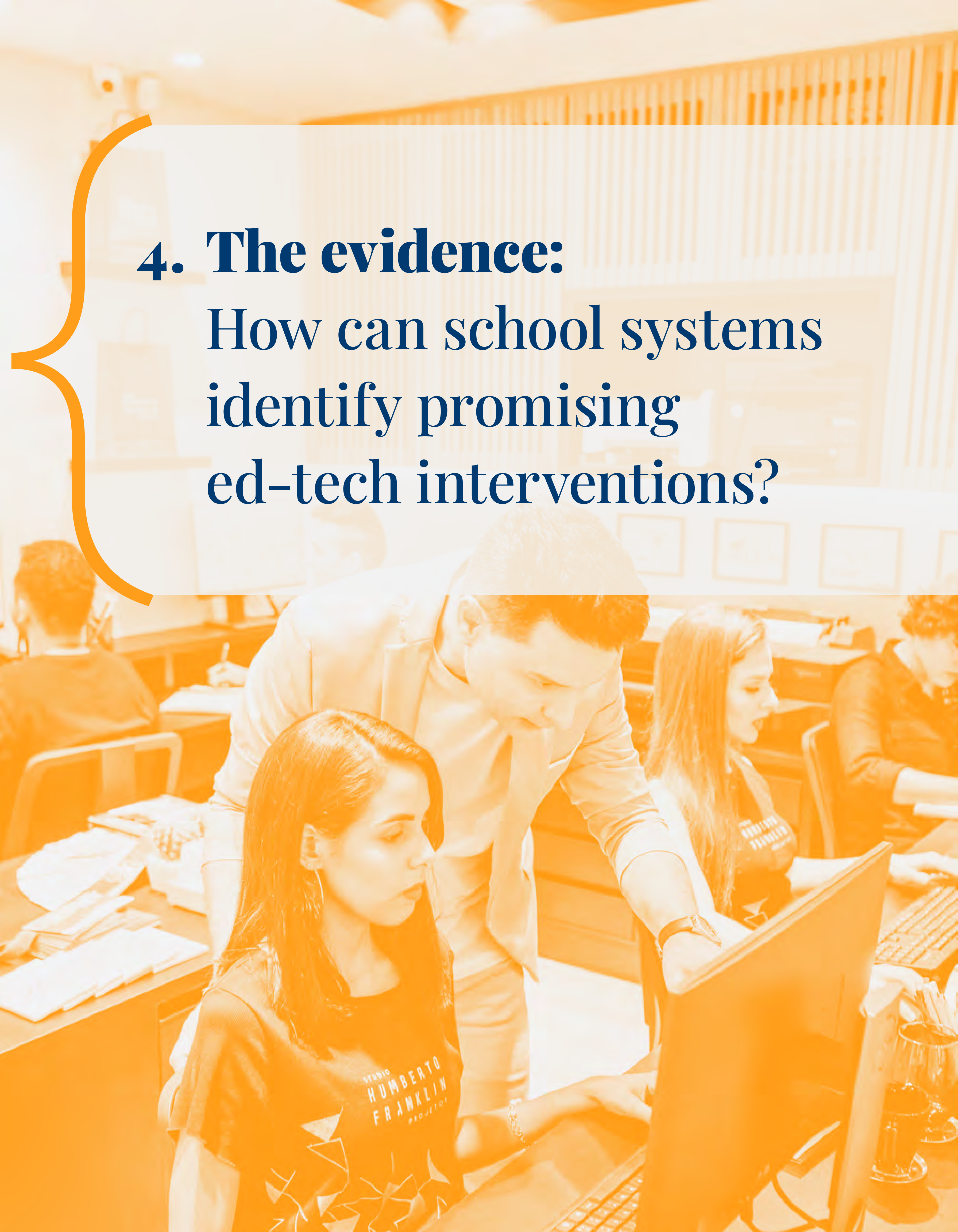
The second part, and possibly the hardest, is to elicit the beliefs of school leaders, teachers, and students on the potential of technology to improve current instructional practices. Asking these actors whether they believe technology in general, or specific interventions, are likely to be helpful is not enough; such statements are likely to be rife with social desirability. Instead, evoking candid responses will require more creative approaches, such as



asking about school-level norms around lesson preparation, willingness to adopt new pedagogical approaches, confidence in current instructional approaches, and mapping of current practices that could benefit from technological enhancement (e.g., classroom assessments). It may also require asking teachers about the types of activities that engage students most/least, and asking students about their perceptions about the extent to which their teachers regularly demonstrate enthusiasm for the adoption of innovations (e.g., creativity, enthusiasm, and eagerness for problem-solving, among others).

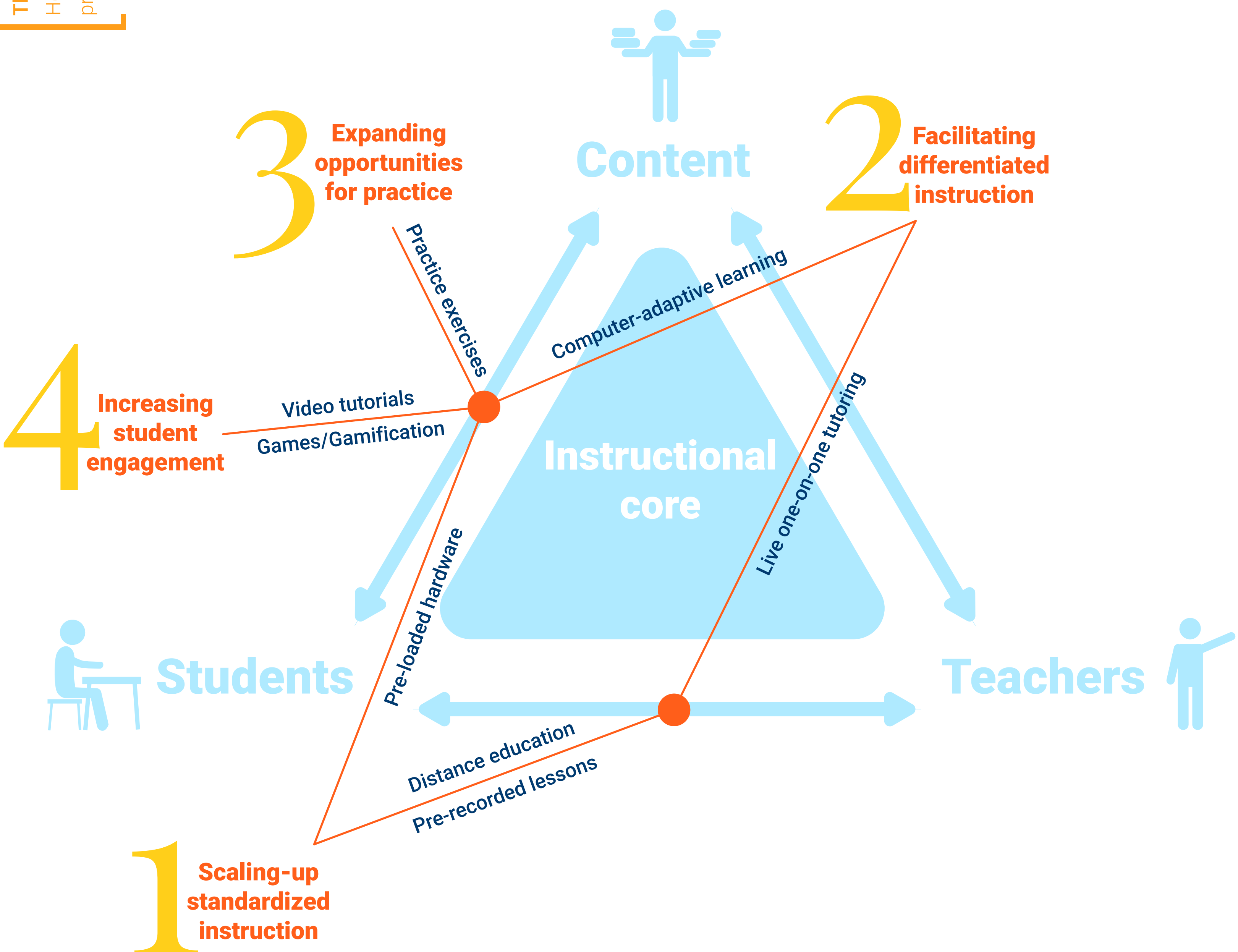
This diagnosis is necessary, but not sufficient. It can help decisionmakers pinpoint the specific needs of their school system, identify potential roadblocks for technology adoption, and the willingness of the main agents of the system to embrace technology-enabled instruction. Yet, just because a given intervention is popular, it does not mean that it should be adopted. The surveys can help set the scope for what is possible, but among feasible options, it is imperative that decisionmakers take a close look at the evidence, not just to know "what works," but rather to understand which needs can be best addressed by technology, what types of interventions are available to address those needs, and in what contexts they have worked most or least well. This is precisely the focus of the next section.

4. The evidence: How can school systems identify promising ed-tech interventions?



An important next step in the process of assessing the potential of investing in education technology is to take a close look at the best available evidence on ed-tech interventions. To assist decisionmakers in this process, in this section, we first identify what we see as four potential comparative advantages of technology to improve student learning in developing countries and then review the evidence on these policy and program interventions (Figure 1). Ours is not the only way to classify the interventions we discuss (e.g., video tutorials could be considered as a strategy to scale up instruction or increase student engagement), but we believe it may be useful to highlight the needs that they could address and why technology is well positioned to do so. Our purpose is to shift current policy debates around ed-tech, from the predominant "supply-driven" approach that only considers what ed-tech products have already been evaluated—regardless of their actual potential to improve learning—to a "demand-driven" approach that draws from the learning sciences to establish what we want to know and how much we know about it.

Figure 2: Comparative advantages of technology



Adapted from Cohen and Ball (1999).

In surveying the evidence, we began by compiling studies from prior general and ed-tech specific evidence reviews that some of us have written (Cifuentes & Ganimian, 2018; Ganimian & Murnane, 2016; Muralidharan, Singh, et al., 2019) and from ed-tech reviews conducted by others (namely, Bulman & Fairlie, 2016; Escueta et al., forthcoming; Tauson & Stannard, 2018). Then, we tracked the studies cited by the ones we had previously read and reviewed those, as well. In identifying studies for inclusion, we focused on experimental and quasi-experimental evaluations of education technology interventions from pre-school to secondary school in low- and middle-income countries that were released between 2000 and 2020. We only included interventions that sought to improve student learning directly (i.e., students' interaction with the material), as opposed to interventions that have impacted achievement indirectly, by reducing teacher absence (e.g., Duflo, Hanna, & Ryan, 2012) or increasing parental engagement (e.g., Berlinski, Busso, Dinkelman, & Martinez, 2017). This process yielded 37 studies in 20 countries (see the full list of studies in Error: no se encontró el origen de la referencia). In our discussion, we highlight examples from the latest research to draw attention to newer insights from this rapidly evolving literature.

When discussing specific studies, we report the magnitude of the effects of interventions using standard deviations (SDs). SDs are a widely used metric in research to express the effect of a program or policy with respect to a business-as-usual condition (e.g., test scores). There are several ways to make sense of them. One is to categorize the magnitude of the effects based on the results of impact evaluations. In developing countries, effects below 0.2 SDs are considered to be small, effects between 0.2 and 0.4 SDs are medium, and those above 0.4 SDs are large (for reviews that estimate the average effect of groups of interventions, called "meta analyses," see e.g., Conn, 2017; Kremer, Brannen, & Glennerster, 2013; McEwan, 2014; Snilstveit et al., 2015).

Scaling up standardized instruction

One of the ways in which technology may improve the quality of education is through its capacity to deliver standardized quality content at scale. This feature of technology may be particularly useful in three types of settings: (a) those in "hard-to-staff" schools (i.e., schools that struggle to recruit teachers with the requisite training and experience—typically, in rural and/or remote areas) (see, e.g., Urquiola & Vegas, 2005); (b) those in which many teachers are frequently absent from school (e.g., Chaudhury, Hammer, Kremer, Muralidharan, & Rogers, 2006; Muralidharan, Das, Holla, & Mohpal, 2017); and/or (c) those in which teachers have low levels of pedagogical and subject matter expertise (e.g., Bietenbeck, Piopiunik, & Wiederhold, 2018; Bold et al., 2017; Metzler & Woessmann, 2012; Santibañez, 2006) and do not have opportunities to observe and receive feedback (e.g., Bruns, Costa, & Cunha, 2018; Cilliers, Fleisch, Prinsloo, & Taylor, 2018). Technology could address this problem by: (a) disseminating lessons delivered by qualified teachers to a large number of students (e.g., through prerecorded or live lessons); (b) enabling distance education (e.g., for students in remote areas and/or during periods of school closures); and (c) distributing hardware preloaded with educational materials.

Prerecorded lessons. Technology seems to be well placed to amplify the impact of effective teachers by disseminating their lessons. Evidence on the impact of prerecorded lessons is encouraging, but not conclusive. Some initiatives that have used short instructional videos to complement regular instruction, in conjunction with other learning materials, have raised student learning on independent assessments. For example, Beg et al. (2020) evaluated an initiative in Punjab, Pakistan in which grade 8 classrooms received an intervention that included short videos to substitute live instruction, quizzes for students to practice the material from every lesson, tablets for teachers to learn the material and follow the lesson, and LED screens to project the videos onto a classroom screen. After six months, the intervention improved the performance of students on independent tests of math and science by 0.19 and 0.24 SDs, respectively but had no discernible effect on the math and science section of Punjab's high-stakes exams.

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One study suggests that approaches that are far less technologically sophisticated can also improve learning outcomes—especially, if the businessasusual instruction is of low quality. For example, Naslund-Hadley, Parker, and Hernandez-Agramonte (2014) evaluated a preschool math program in Cordillera, Paraguay that used audio segments and written materials four days per week for an hour per day during the school day. After five months, the intervention improved math scores by 0.16 SDs, narrowing gaps between low- and high-achieving students, and between those with and without teachers with formal training in early childhood education.

Yet, the integration of prerecorded material into regular instruction has not always been successful. For example, de Barros (2020) evaluated an intervention that combined instructional videos for math and science with infrastructure upgrades (e.g., two "smart" classrooms, two TVs, and two tablets), printed workbooks for students, and in-service training for teachers of students in grades 9 and 10 in Haryana, India (all materials were mapped onto the official curriculum). After 11 months, the intervention negatively impacted math achievement (by 0.08 SDs) and had no effect on science (with respect to business as usual classes). It reduced the share of lesson time that teachers devoted to instruction and negatively impacted an index of instructional quality. Likewise, Seo (2017) evaluated several combinations of infrastructure (solar lights and TVs) and prerecorded videos (in English and/or bilingual) for grade 11 students in northern Tanzania and found that none of the variants improved student learning, even when the videos were used. The study reports effects from the infrastructure component across variants, but as others have noted (Muralidharan, Romero, & Wüthrich, 2019), this approach to estimating impact is problematic.

A very similar intervention delivered after school hours, however, had sizeable effects on students' basic skills. Chiplunkar, Dhar, and Nagesh (2020) evaluated an initiative in Chennai (the capital city of the state of Tamil Nadu, India) delivered by the same organization as above that combined short videos that explained key concepts in math and science with worksheets, facilitator-led instruction, small groups for peer-to-peer learning, and occasional career counseling and guidance for grade 9 students. These lessons took place after school for one hour, five times a week. After 10 months, it had large effects on students' achievement as measured by tests of basic skills in math and reading, but no effect on a standardized high-stakes test in grade 10 or socio-emotional skills (e.g., teamwork, decisionmaking, and communication).

Drawing general lessons from this body of research is challenging for at least two reasons. First, all of the studies above have evaluated the impact of prerecorded lessons combined with several other components (e.g., hardware, print materials, or other activities). Therefore, it is possible that the effects found are due to these additional components, rather than to the recordings themselves, or to the interaction between the two (see Muralidharan, 2017 for a discussion of the challenges of interpreting "bundled" interventions). Second, while these studies evaluate some type of prerecorded lessons, none examines the content of such lessons. Thus, it seems entirely plausible that the direction and magnitude of the effects depends largely on the quality of the recordings (e.g., the expertise of the teacher recording it, the amount of preparation that went into planning the recording, and its alignment with best teaching practices).

These studies also raise three important questions worth exploring in future research. One of them is why none of the interventions discussed above had effects on high-stakes exams, even if their materials are typically mapped onto the official curriculum. It is possible that the official curricula are simply too challenging for students in these settings, who are several grade levels behind expectations and who often need to reinforce basic skills (see Pritchett & Beatty, 2015). Another question is whether these interventions have long-term effects on teaching practices. It seems plausible that, if these interventions are deployed in contexts with low teaching quality, teachers may learn something from watching the videos or listening to the recordings with students. Yet another question is whether these interventions make it easier for schools to deliver instruction to students whose native language is other than the official medium of instruction.

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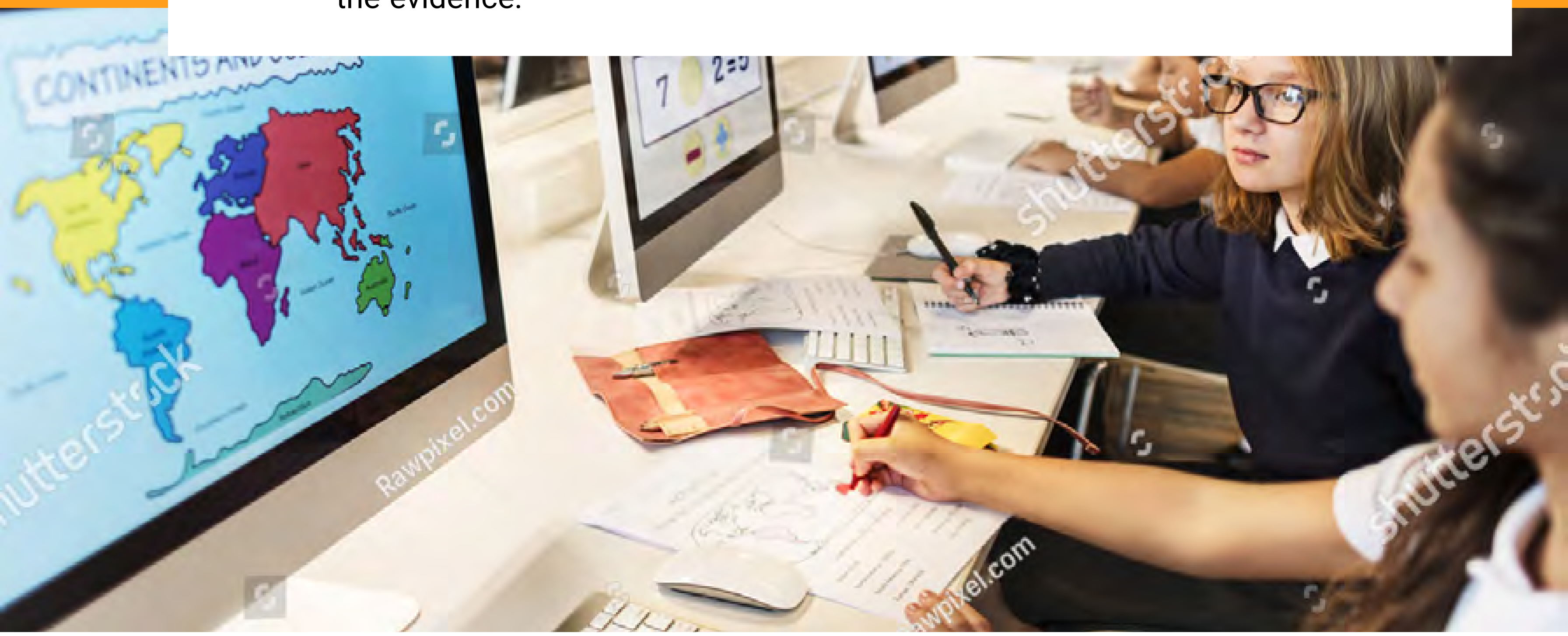
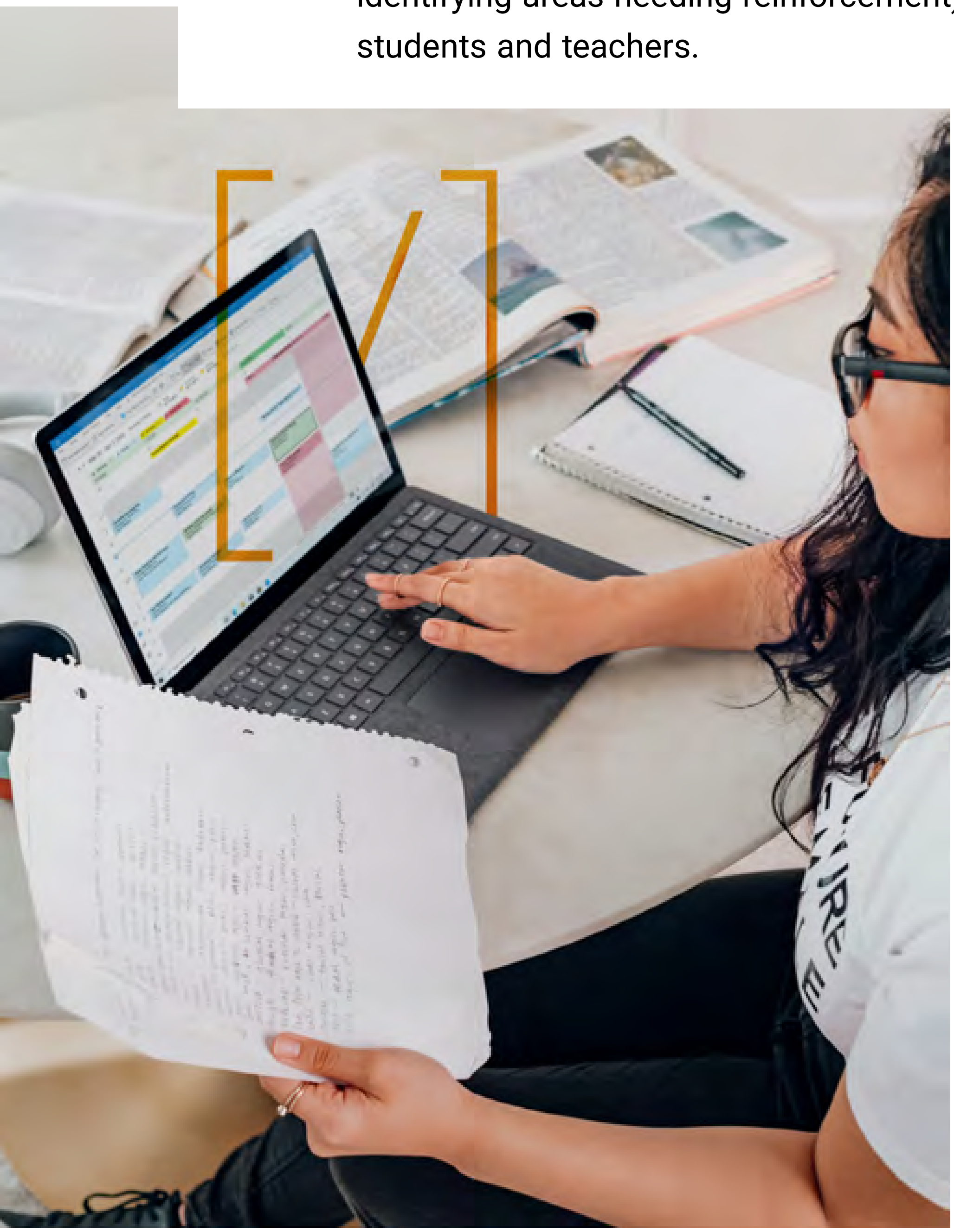
Distance education. Technology can also allow students living in remote areas to access education. The evidence on these initiatives is encouraging. For example, Johnston and Ksoll (2017) evaluated a program that broadcasted live instruction via satellite to rural primary school students in the Volta and Greater Accra regions of Ghana. For this purpose, the program also equipped classrooms with the technology needed to connect to a studio in Accra, including solar panels, a satellite modem, a projector, a webcam, microphones, and a computer with interactive software. After two years, the intervention improved the numeracy scores of students in grades 2 through 4, and some foundational literacy tasks, but no effect on attendance or classroom time devoted to instruction, as captured by school visits. The authors interpreted these results as suggesting that the gains in achievement may be due to improving the quality of instruction that children received (as opposed to increased instructional time). Naik, Chitre, Bhalla, and Rajan (2019) evaluated a similar program in the Indian state of Karnataka and also found positive effects on learning outcomes, but it is not clear whether those effects are due to the program or due to differences in the groups of students they compared to estimate the impact of the initiative.

In one context (Mexico), this type of distance education had positive long-term effects. Navarro-Sola (2019) took advantage of the staggered rollout of the telesecundarias (i.e., middle schools with lessons broadcasted through satellite TV) in 1968 to estimate its impact. The policy had short-term effects on students' enrollment in school: For every telesecundaria per 50 children, 10 students enrolled in middle school and two pursued further education. It also had a long-term influence on the educational and employment trajectory of its graduates. Each additional year of education induced by the policy increased average income by nearly 18 percent. This effect was attributable to more graduates entering the labor force and shifting from agriculture and the informal sector. Similarly, Fabregas (2019) leveraged a later expansion of this policy in 1993 and found that each additional telesecundaria per 1,000 adolescents led to an average increase of 0.2 years of education, and a decline in fertility for women, but no conclusive evidence of long-term effects on labor market outcomes.

It is crucial to interpret these results keeping in mind the settings where the interventions were implemented. As we mention above, part of the reason why they have proven effective is that the "counterfactual" conditions for learning (i.e., what would have happened to students in the absence of such programs) was either to not have access to schooling or to be exposed to low-quality instruction. School systems interested in taking up similar interventions should assess the extent to which their students (or parts of their student population) find themselves in similar conditions to the subjects of the studies above. This illustrates the importance of assessing the needs of a system before reviewing the evidence.



Preloaded hardware. Technology also seems well positioned to disseminate educational materials. Specifically, hardware (e.g., desktop computers, laptops, or tablets) could also help deliver educational software (e.g., word processing, reference texts, and/or games). In theory, these materials could not only undergo a quality assurance review (e.g., by curriculum specialists and teachers), but also draw on the interactions with students for adjustments (e.g., identifying areas needing reinforcement) and enable interactions between students and teachers.



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In practice, however, most initiatives that have provided students with free computers, laptops, and netbooks do not leverage any of the opportunities mentioned above. Instead, they install a standard set of educational materials and hope that students find them helpful enough to take them up on their own. Students rarely do so, and instead use the laptops for recreational purposes—often, to the detriment of their learning (see, e.g., Malamud & Pop-Eleches, 2011). In fact, free netbook initiatives have not only consistently failed to improve academic achievement in math or language (e.g., Cristia et al., 2017), but they have had no impact on students' general computer skills (e.g., Beuermann et al., 2015). Some of these initiatives have had small impacts on cognitive skills, but the mechanisms through which those effects occurred remains unclear.

To our knowledge, the only successful deployment of a free laptop initiative was one in which a team of researchers equipped the computers with remedial software. Mo et al. (2013) evaluated a version of the One Laptop per Child (OLPC) program for grade 3 students in migrant schools in Beijing, China in which the laptops were loaded with a remedial software mapped onto the national curriculum for math (similar to the software products that we discuss under "practice exercises" below). After nine months, the program improved math achievement by 0.17 SDs and computer skills by 0.33 SDs. If a school system decides to invest in free laptops, this study suggests that the quality of the software on the laptops is crucial.

To date, however, the evidence suggests that children do not learn more from interacting with laptops than they do from textbooks. For example, Bando, Gallego, Gertler, and Romero (2016) compared the effect of free laptop and textbook provision in 271 elementary schools in disadvantaged areas of Honduras. After seven months, students in grades 3 and 6 who had received the laptops performed on par with those who had received the textbooks in math and language. Further, even if textbooks essentially become obsolete at the end of each school year, whereas laptops can be reloaded with new materials for each year, the costs of laptop provision (not just the hardware, but also the technical assistance, Internet, and training associated with it) are not yet low enough to make them a more cost-effective way of delivering content to students.

Evidence on the provision of tablets equipped with software is encouraging but limited. For example, de Hoop et al. (2020) evaluated a composite intervention for first grade students in Zambia's Eastern Province that combined infrastructure (electricity via solar power), hardware (projectors and tablets), and educational materials (lesson plans for teachers and interactive lessons for students, both loaded onto the tablets and mapped onto the official Zambian curriculum). After 14 months, the intervention had improved student early-grade reading by 0.4 SDs, oral vocabulary scores by 0.25 SDs, and early-grade math by 0.22 SDs. It also improved students' achievement by 0.16 on a locally developed assessment. The multifaceted nature of the program, however, makes it challenging to identify the components that are driving the positive effects. Pitchford (2015) evaluated an intervention that provided tablets equipped with educational "apps," to be used for 30 minutes per day for two months to develop early math skills among students in grades 1 through 3 in Lilongwe, Malawi. The evaluation found positive impacts in math achievement, but the main study limitation is that it was conducted in a single school.

Facilitating differentiated instruction

Another way in which technology may improve educational outcomes is by facilitating the delivery of differentiated or individualized instruction. Most developing countries massively expanded access to schooling in recent decades by building new schools and making education more affordable, both by defraying direct costs, as well as compensating for opportunity costs (Duflo, 2001; World Bank, 2018). These initiatives have not only rapidly increased the number of students enrolled in school, but have also increased the variability in students' preparation for schooling. Consequently, a large number of students perform well below grade-based curricular expectations (see, e.g., Duflo, Dupas, & Kremer, 2011; Pritchett & Beatty, 2015). These students are unlikely to get much from "one-size-fits-all" instruction, in which a single teacher delivers instruction deemed appropriate for the middle (or top) of the achievement distribution (Banerjee & Duflo, 2011). Technology could potentially help these students by providing them with: (a) instruction and opportunities for practice that adjust to the level and pace of preparation of each individual (known as "computer-adaptive learning" (CAL)); or (b) live, one-on-one tutoring.

Computer-adaptive learning. One of the main comparative advantages of technology is its ability to diagnose students' initial learning levels and assign students to instruction and exercises of appropriate difficulty. No individual teacher—no matter how talented—can be expected to provide individualized instruction to all students in his/her class simultaneously. In this respect, technology is uniquely positioned to complement traditional teaching. This use of technology could help students master basic skills and help them get more out of schooling.

Although many software products evaluated in recent years have been categorized as CAL, many rely on a relatively coarse level of differentiation at an initial stage (e.g., a diagnostic test) without further differentiation. We discuss these initiatives under the category of "increasing opportunities for practice" below. CAL initiatives complement an initial diagnostic with dynamic adaptation (i.e., at each response or set of responses from students) to adjust both the initial level of difficulty and rate at which it increases or decreases, depending on whether students' responses are correct or incorrect.

Existing evidence on this specific type of programs is highly promising. Most famously, Banerjee et al. (2007) evaluated CAL software in Vadodara, in the Indian state of Gujarat, in which grade 4 students were offered two hours of shared computer time per week before and after school, during which they played games that involved solving math problems. The level of difficulty of such problems adjusted based on students' answers. This program improved math achievement by 0.35 and 0.47 SDs after one and two years of implementation, respectively. Consistent with the promise of personalized learning, the software improved achievement for all students. In fact, one year after the end of the program, students assigned to the program still performed 0.1 SDs better than those assigned to a business as usual condition. More recently, Muralidharan, Singh, et al. (2019) evaluated a "blended learning" initiative in which students in grades 4 through 9 in Delhi, India received 45 minutes of interaction with CAL software for math and language, and 45 minutes of small group instruction before or after going to school. After only 4.5 months, the program improved achievement by 0.37 SDs in math and 0.23 SDs in Hindi. While all students benefited from the program in absolute terms, the lowest performing students benefited the most in relative terms, since they were learning very little in school.

We see two important limitations from this body of research. First, to our knowledge, none of these initiatives has been evaluated when implemented during the school day. Therefore, it is not possible to distinguish the effect of the adaptive software from that of additional instructional time. Second, given that most of these programs were facilitated by local instructors, attempts to distinguish the effect of the software from that of the instructors has been mostly based on noncausal evidence. A frontier challenge in this body of research is to understand whether CAL software can increase the effectiveness of school-based instruction by substituting part of the regularly scheduled time for math and language instruction.

Live one-on-one tutoring. Recent improvements in the speed and quality of videoconferencing, as well as in the connectivity of remote areas, have enabled yet another way in which technology can help personalization: live (i.e., real-time) one-on-one tutoring. While the evidence on in-person tutoring is scarce in developing countries, existing studies suggest that this approach works best when it is used to personalize instruction (see, e.g., Banerjee et al., 2007; Banerji, Berry, & Shotland, 2015; Cabezas, Cuesta, & Gallego, 2011).

There are almost no studies on the impact of online tutoring—possibly, due to the lack of hardware and Internet connectivity in low- and middle-income countries. One exception is Chemin and Oledan (2020)'s recent evaluation of an online tutoring program for grade 6 students in Kianyaga, Kenya to learn English from volunteers from a Canadian university via Skype (videoconferencing software) for one hour per week after school. After 10 months, program beneficiaries performed 0.22 SDs better in a test of oral comprehension, improved their comfort using technology for learning, and became more willing to engage in cross-cultural communication. Importantly, while the tutoring sessions used the official English textbooks and sought in part to help students with their homework, tutors were trained on several strategies to teach to each student's individual level of preparation, focusing on basic skills if necessary. To our knowledge, similar initiatives within a country have not yet been rigorously evaluated.

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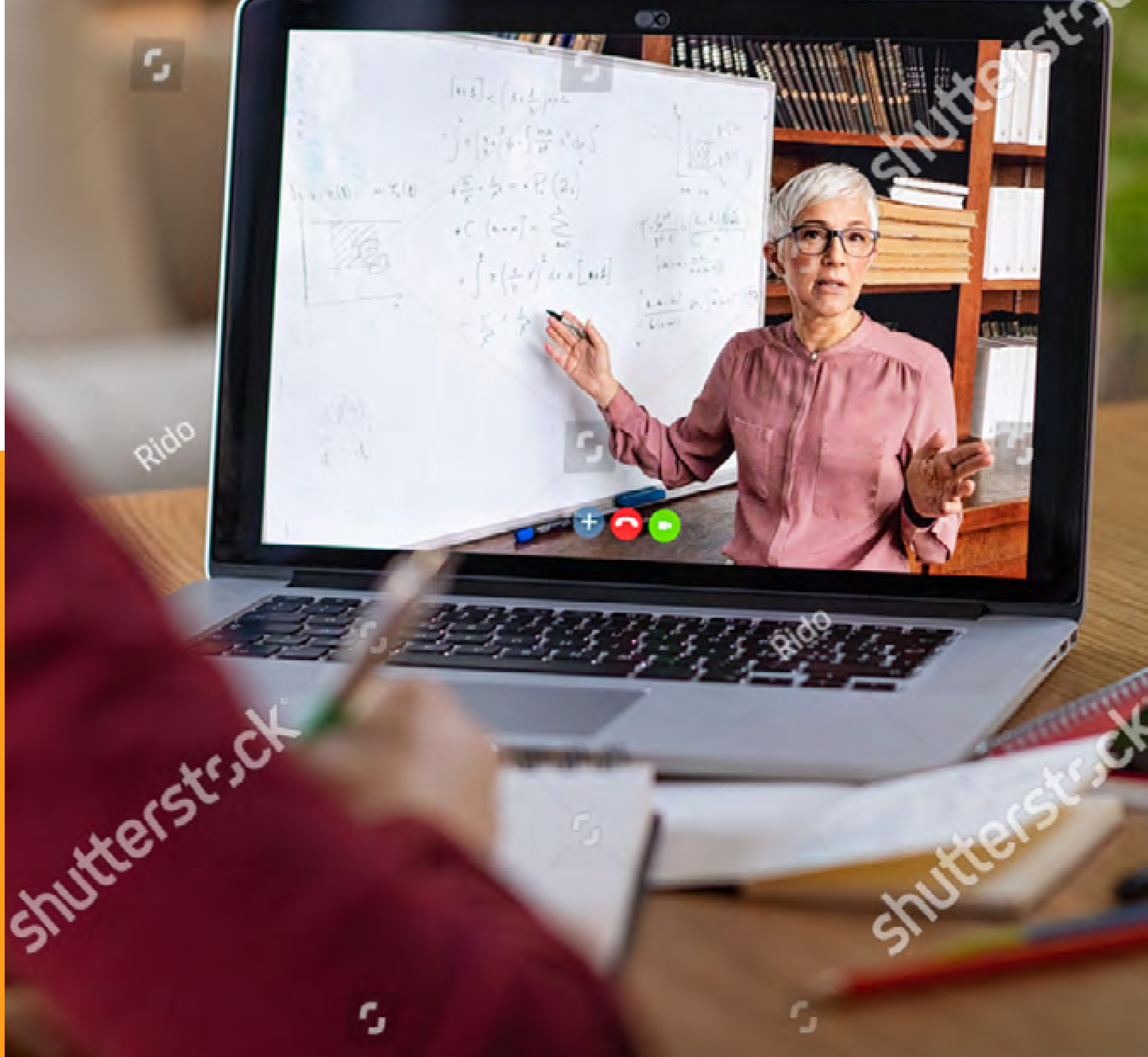

Expanding opportunities for practice

A third way in which technology may improve the quality of education is by providing students with additional opportunities for practice. In many developing countries, lesson time is primarily devoted to lectures, in which the teacher explains the topic and the students passively copy explanations from the blackboard. This setup leaves little time for in-class practice. Consequently, students who did not understand the explanation of the material during lecture struggle when they have to solve homework assignments on their own. Technology could potentially address this problem by allowing students to review topics at their own pace.

Practice exercises. Technology can help students get more out of traditional instruction by providing them with opportunities to implement what they learn in class. This approach could, in theory, allow some students to anchor their understanding of the material through trial and error (i.e., by realizing what they may not have understood correctly during lecture and by getting better acquainted with special cases not covered in-depth in class).

Existing evidence on practice exercises reflects both the promise and the limitations of this use of technology in developing countries. For example, Lai et al. (2013) evaluated a program in Shaanxi, China where students in grades 3 and 5 were required to attend two 40-minute remedial sessions per week in which they first watched videos that reviewed the material that had been introduced in their math lessons that week and then played games to practice the skills introduced in the video. After four months, the intervention improved math achievement by 0.12 SDs. Many other evaluations of comparable interventions have found similar small-to-moderate results (see, e.g., Lai, Luo, Zhang, Huang, & Rozelle, 2015; Lai et al., 2012; Mo et al., 2015; Pitchford, 2015). These effects, however, have been consistently smaller than those of initiatives that adjust the difficulty of the material based on students' performance (e.g., Banerjee et al., 2007; Muralidharan, Singh, et al., 2019). We hypothesize that these programs do little for students who perform several grade levels behind curricular expectations, and who would benefit more from a review of foundational concepts from earlier grades.

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We see two important limitations from this research. First, most initiatives that have been evaluated thus far combine instructional videos with practice exercises, so it is hard to know whether their effects are driven by the former or the latter. In fact, the program in China described above allowed students to ask their peers whenever they did not understand a difficult concept, so it potentially also captured the effect of peer-to-peer collaboration. To our knowledge, no studies have addressed this gap in the evidence.

Second, most of these programs are implemented before or after school, so we cannot distinguish the effect of additional instructional time from that of the actual opportunity for practice. The importance of this question was first highlighted by Linden (2008), who compared two delivery mechanisms for game-based remedial math software for students in grades 2 and 3 in a network of schools run by a nonprofit organization in Gujarat, India: one in which students interacted with the software during the school day and another one in which students interacted with the software before or after school (in both cases, for three hours per day). After a year, the first version of the program had negatively impacted students' math achievement by 0.57 SDs and the second one had a null effect. This study suggested that computer-assisted learning is a poor substitute for regular instruction when it is of high quality, as was the case in this well-functioning private network of schools.

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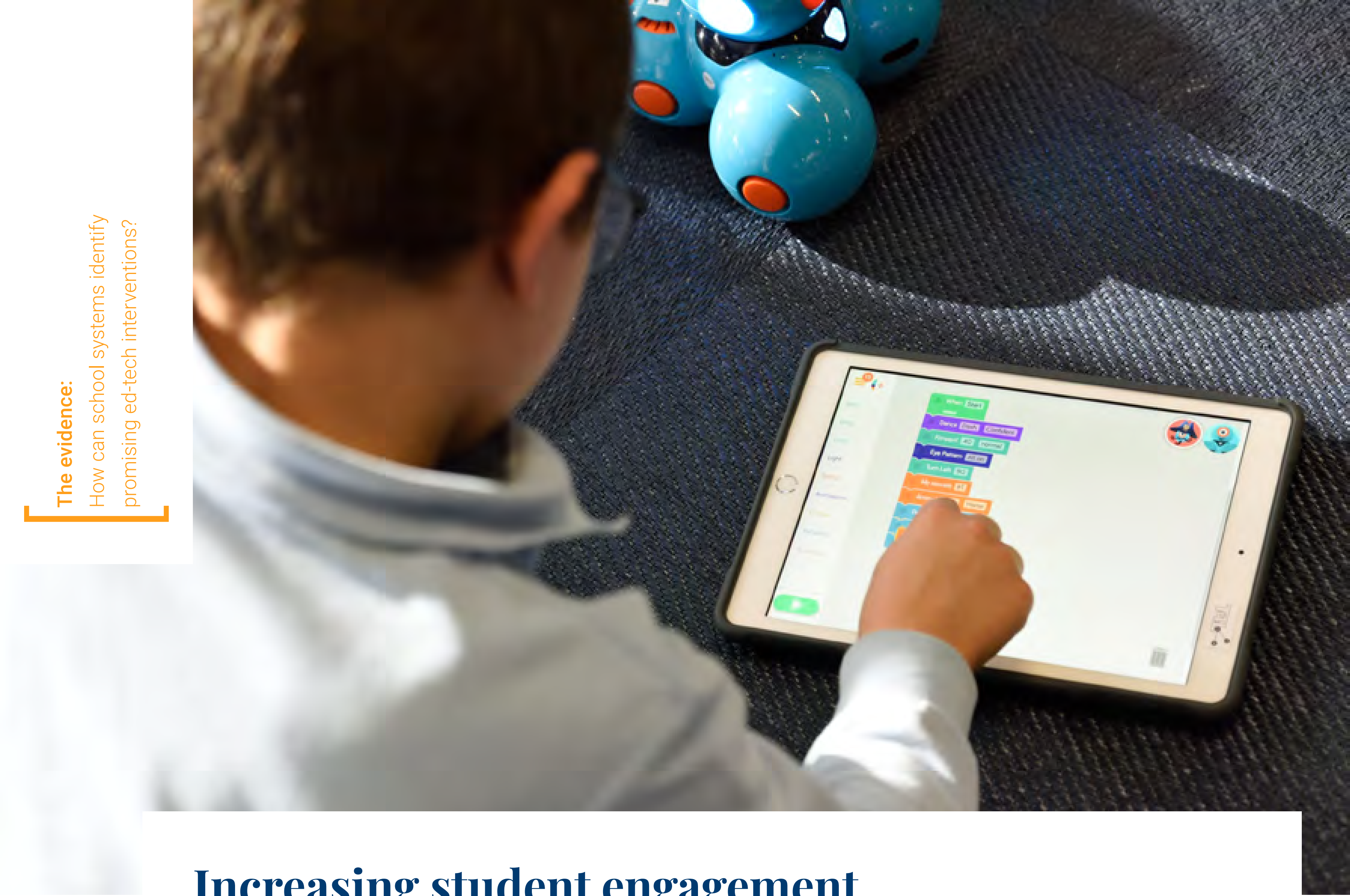
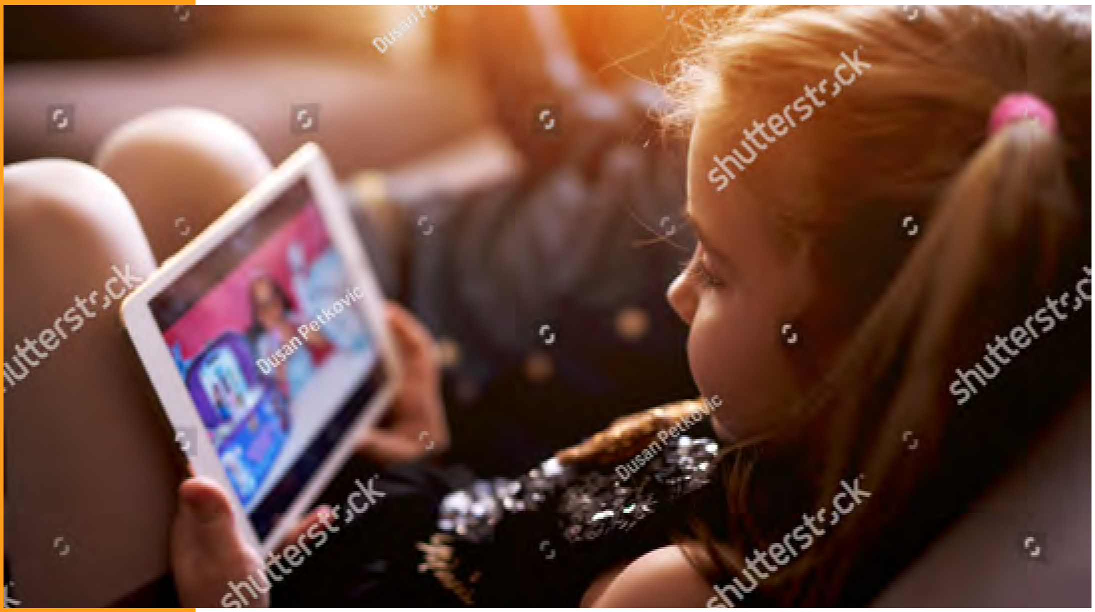
In recent years, several studies have sought to remedy this shortcoming. Mo et al. (2014) were among the first to evaluate practice exercises delivered during the school day. They evaluated an initiative in Shaanxi, China in which students in grades 3 and 5 were required to interact with the software similar to the one in Lai et al. (2013) for two 40-minute sessions per week. The main limitation of this study, however, is that the program was delivered during regularly scheduled computer lessons, so it could not determine the impact of substituting regular math instruction. Similarly, Mo et al. (2020) evaluated a self-paced and a teacher-directed version of a similar program for English for grade 5 students in Qinghai, China. Yet, the key shortcoming of this study is that the teacher-directed version added several components that may also influence achievement, such as increased opportunities for teachers to provide students with personalized assistance when they struggled with the material. Ma, Fairlie, Loyalka, and Rozelle (2020) compared the effectiveness of additional time-delivered remedial instruction for students in grades 4 to 6 in Shaanxi, China through either computer-assisted software or using workbooks. This study indicates whether additional instructional time is more effective when using technology, but it does not address the question of whether school systems may improve the productivity of instructional time during the school day by substituting teacher-led with computer-assisted instruction.



Increasing student engagement

Another way in which technology may improve education is by increasing students' engagement with the material. In many school systems, regular "chalk and talk" instruction prioritizes time for teachers' exposition over opportunities for students to ask clarifying questions and/or contribute to class discussions. This, combined with the fact that many developing-country classrooms include a very large number of students (see, e.g., Angrist & Lavy, 1999; Duflo, Dupas, & Kremer, 2015), may partially explain why the majority of those students are several grade levels behind curricular expectations (e.g., Muralidharan, Singh, et al., 2019; Muralidharan & Zieleniak, 2014; Pritchett & Beatty, 2015). Technology could potentially address these challenges by: (a) using video tutorials for self-paced learning and (b) presenting exercises as games and/or gamifying practice.

Video tutorials. Technology can potentially increase student effort and understanding of the material by finding new and more engaging ways to deliver it. Video tutorials designed for self-paced learning—as opposed to videos for whole class instruction, which we discuss under the category of "prerecorded lessons" above—can increase student effort in multiple ways, including: allowing students to focus on topics with which they need more help, letting them correct errors and misconceptions on their own, and making the material appealing through visual aids. They can increase understanding by breaking the material into smaller units and tackling common misconceptions.



In spite of the popularity of instructional videos, there is relatively little evidence on their effectiveness. Yet, two recent evaluations of different versions of the Khan Academy portal, which mainly relies on instructional videos, offer some insight into their impact. First, Ferman, Finamor, and Lima (2019) evaluated an initiative in 157 public primary and middle schools in five cities in Brazil in which the teachers of students in grades 5 and 9 were taken to the computer lab to learn math from the platform for 50 minutes per week. The authors found that, while the intervention slightly improved students' attitudes toward math, these changes did not translate into better performance in this subject. The authors hypothesized that this could be due to the reduction of teacher-led math instruction.

More recently, Büchel, Jakob, Kühnhanss, Steffen, and Brunetti (2020) evaluated an after-school, offline delivery of the Khan Academy portal in grades 3 through 6 in 302 primary schools in Morazán, El Salvador. Students in this study received 90 minutes per week of additional math instruction (effectively nearly doubling total math instruction per week) through teacher-led regular lessons, teacher-assisted Khan Academy lessons, or similar lessons assisted by technical supervisors with no content expertise. (Importantly, the first group provided differentiated instruction, which is not the norm in Salvadorian schools). All three groups outperformed both schools without any additional lessons and classrooms without additional lessons in the same schools as the program. The teacher-assisted Khan Academy lessons performed 0.24 SDs better, the supervisor-led lessons 0.22 SDs better, and the teacher-led regular lessons 0.15 SDs better, but the authors could not determine whether the effects across versions were different.

Together, these studies suggest that instructional videos work best when provided as a complement to, rather than as a substitute for, regular instruction. Yet, the main limitation of these studies is the multifaceted nature of the Khan Academy portal, which also includes other components found to positively improve student achievement, such as differentiated instruction by students' learning levels. While the software does not provide the type of personalization discussed above, students are asked to take a placement test and, based on their score, teachers assign them different work. Therefore, it is not clear from these studies whether the effects from Khan Academy are driven by its instructional videos or to the software's ability to provide differentiated activities when combined with placement tests.

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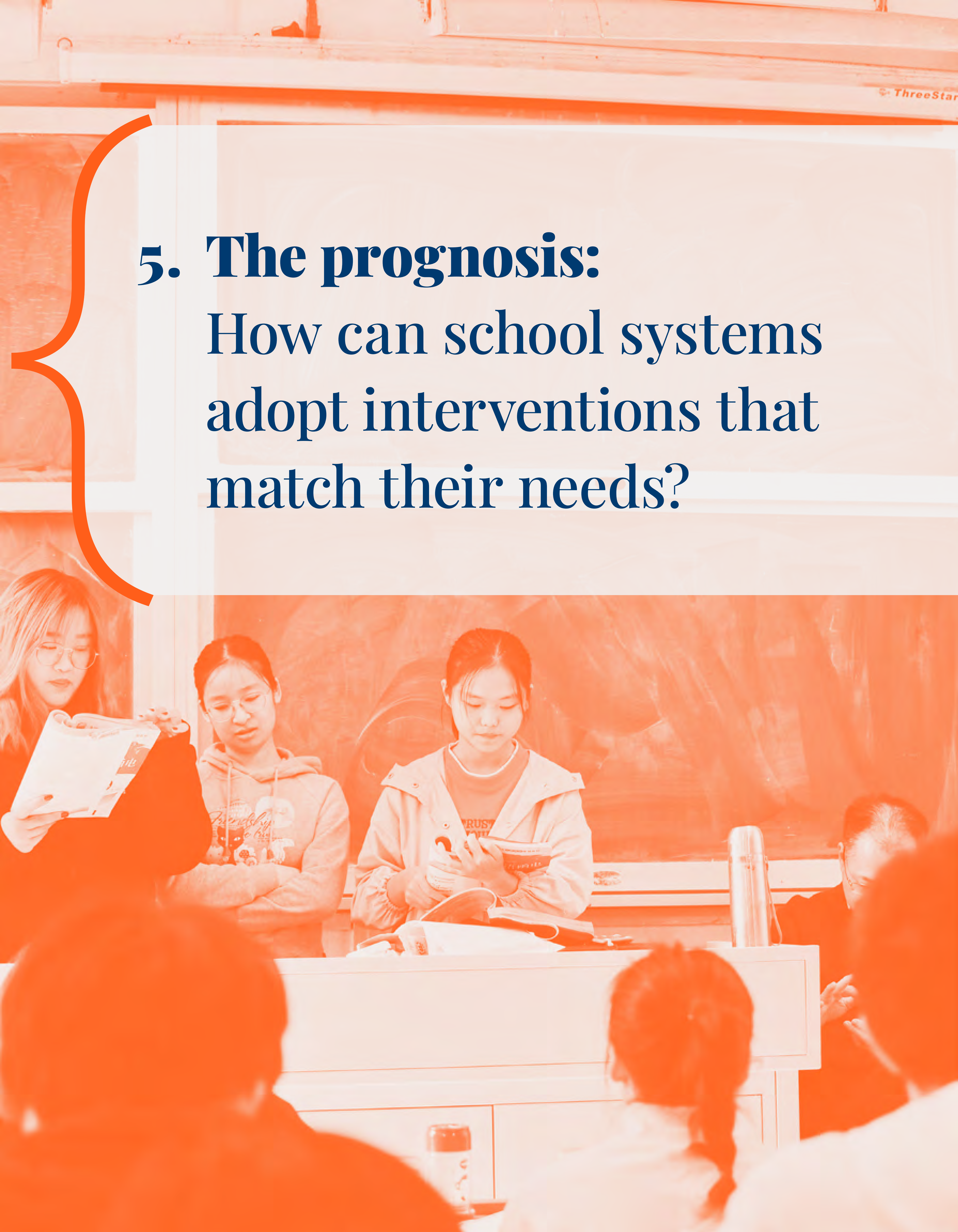
Games and gamification. Technology can also increase student engagement by presenting exercises as games and/or by encouraging students to play and compete with others (e.g., using leaderboards and rewards)—an approach known as "gamification." Both approaches can increase student motivation and effort by presenting students with entertaining opportunities for practice and by leveraging peers as commitment devices.

There are very few studies on the effects of games and gamification in low- and middle-income countries. Recently, Araya, Arias Ortiz, Bottan, and Cristia (2019) evaluated an initiative in which grade 4 students in Santiago, Chile were required to participate in two 90-minute sessions per week during the school day with instructional math software featuring individual and group competitions (e.g., tracking each student's standing in his/her class and tournaments between sections). After nine months, the program led to improvements of 0.27 SDs in the national student assessment in math (it had no spillover effects on reading). However, it had mixed effects on non-academic outcomes. Specifically, the program increased students' willingness to use computers to learn math, but, at the same time, increased their anxiety toward math and negatively impacted students' willingness to collaborate with peers. Finally, given that one of the weekly sessions replaced regular math instruction and the other one represented additional math instructional time, it is not clear whether the academic effects of the program are driven by the software or the additional time devoted to learning math.

A careful review of the evidence can help decisionmakers identify interventions with promising results. An understanding of the gaps in evidence may also help them decide which features of an intervention need to be monitored closely for effectiveness. To that end, the next step in the process of the adoption of ed-tech innovations is to devise a plan to experiment, monitor, and subsequently scale up the most effective solutions. We devote the next and final section to this question.

5. The prognosis:
How can school systems adopt interventions that match their needs?



The prognosis:
How can school systems adopt interventions that match their needs?

While technology has disrupted most sectors of the economy and changed how we communicate, access information, work, and even play, its impact on schools, teaching, and learning has been much more limited. We believe that the limited impact of technology in education is primarily due to its having been used to replace analog tools, without much consideration given to playing to technology's comparative advantages. When schools use technology to enhance the work of teachers and to improve the quality and quantity of educational content, students will thrive. Further, COVID-19 has laid bare that, in today's environment where pandemics and the effects of climate change are likely to occur, schools cannot always provide in-person education—making the case for investing in education technology.

In this section, we provide five specific and sequential guidelines for decisionmakers to realize the potential of education technology to accelerate student learning.

1. **First, take stock of how your current schools, teachers, and students are engaging with technology.** Carry out a short in-school survey to understand the current practices and potential barriers to adoption of technology (we have included suggested survey instruments in the Appendices); use this information in your decisionmaking process. For example, we learned from conversations with current and former ministers of education from various developing regions that a common limitation to technology use is regulations that hold school leaders accountable for damages to or losses of devices. Another common barrier is lack of access to electricity and Internet, or even the availability of sufficient outlets for charging devices in classrooms. Understanding basic infrastructure and regulatory limitations to the use of education technology is a first necessary step. But addressing these limitations will not guarantee that introducing or expanding technology use will accelerate learning. The next steps are thus necessary.

"In Africa, the biggest limit is connectivity. Fiber is expensive, and we don't have it everywhere. The continent is creating a digital divide between cities, where there is fiber, and the rural areas.
The [Ghanaian] administration put in schools offline/online technologies with books, assessment tools, and open source materials. In deploying this, we are finding that again, teachers are unfamiliar with it. And existing policies prohibit students to bring their own tablets or cell phones. The easiest way to do it would have been to let everyone bring their own device. But policies are against it."

H.E. Matthew Prempeh, Minister of Education of Ghana, on the need to understand the local context.

2.

Second, consider how the introduction of technology may affect the interactions among students, teachers, and content. Our review of the evidence indicates that technology may accelerate student learning when it is used to scale up access to quality content, facilitate differentiated instruction, increase opportunities for practice, or when it increases student engagement. For example, will adding electronic whiteboards to classrooms facilitate access to more quality content or differentiated instruction? Or will these expensive boards be used in the same way as the old chalkboards? Will providing one device (laptop or tablet) to each student facilitate access to more and better content, or offer students more opportunities to practice and learn? Solely introducing technology in classrooms without additional changes is unlikely to lead to improved learning and may be quite costly. If you cannot clearly identify how the interactions among the three key components of the instructional core (teachers, students, and content) may change after the introduction of technology, then it is probably not a good idea to make the investment. See Appendix A for guidance on the types of questions to ask.

3. **Third, once decisionmakers have a clear idea of how education technology can help accelerate student learning in a specific context, it is important to define clear objectives and goals and establish ways to regularly assess progress and make course corrections in a timely manner.** For instance, is the education technology expected to ensure that students in early grades excel in foundational skills—basic literacy and numeracy—by age 10? If so, will the technology provide quality reading and math materials, ample opportunities to practice, and engaging materials such as videos or games? Will teachers be empowered to use these materials in new ways? And how will progress be measured and adjusted?

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4. **Fourth, *How* this kind of reform is approached can matter immensely for its success.** It is easy to nod to issues of "implementation," but that needs to be more than rhetorical. Keep in mind that good use of education technology requires thinking about how it will affect students, teachers, and parents. After all, giving students digital devices will make no difference if they get broken, are stolen, or go unused. Classroom technologies only matter if teachers feel comfortable putting them to work. Since good technology is generally about complementing or amplifying what teachers and students already do, it is almost always a mistake to mandate programs from on high. It is vital that technology be adopted with the input of educators and families and with attention to how it will be used. If technology goes unused or if teachers use it ineffectually, the results will disappoint—no matter the virtuosity of the technology. Indeed, unused education technology can be an unnecessary expenditure for cash-strapped education systems. This is why surveying context, listening to voices in the field, examining how technology is used, and planning for course correction is essential.

5. **Fifth, it is essential to communicate with a range of stakeholders, including teachers, school leaders, parents, and students.** Technology can feel alien in schools, confuse parents and (especially) older educators, or become an alluring distraction. Good communication can help address all of these risks. Taking care to listen to educators and families can help ensure that programs are informed by their needs and concerns. At the same time, deliberately and consistently explaining what technology is and is not supposed to do, how it can be most effectively used, and the ways in which it can make it more likely that programs work as intended. For instance, if teachers fear that technology is intended to reduce the need for educators, they will tend to be hostile; if they believe that it is intended to assist them in their work, they will be more receptive. Absent effective communication, it is easy for programs to "fail" not because of the technology but because of how it was used. In short, past experience in rolling out education programs indicates that it is as important to have a strong intervention design as it is to have a solid plan to socialize it among stakeholders.

6. Conclusions

Although the use of education technology will need to vary by context, after COVID-19, one thing is certain: School systems that are best prepared to use education technology effectively will be better positioned to continue offering quality education in the face of school closures. The COVID-19 school closures have forced school leaders, teachers, parents, and students to engage with technology in new and intensive ways. At the same time, many students living in disadvantaged communities throughout the world—with limited access to power and connectivity—have had their learning opportunities affected, with resulting learning losses that will impact their futures.

This report has sought to provide guidance to decisionmakers throughout the world to realize the potential of education technology. We began by conducting a systematic review of rigorous evaluations of education programs that use technology to improve learning. To date, the evidence suggests that children do not learn more from interacting with laptops than they do from interacting with regular textbooks. So, focusing solely on distributing hardware and expecting to see improved student learning is not recommended.

Instead, the evidence reviewed here suggests that decisionmakers should focus on four potential uses of technology that play to its comparative advantages and complement the work of teachers to accelerate student learning:

1. Scaling up quality instruction – such as through prerecorded quality lessons;

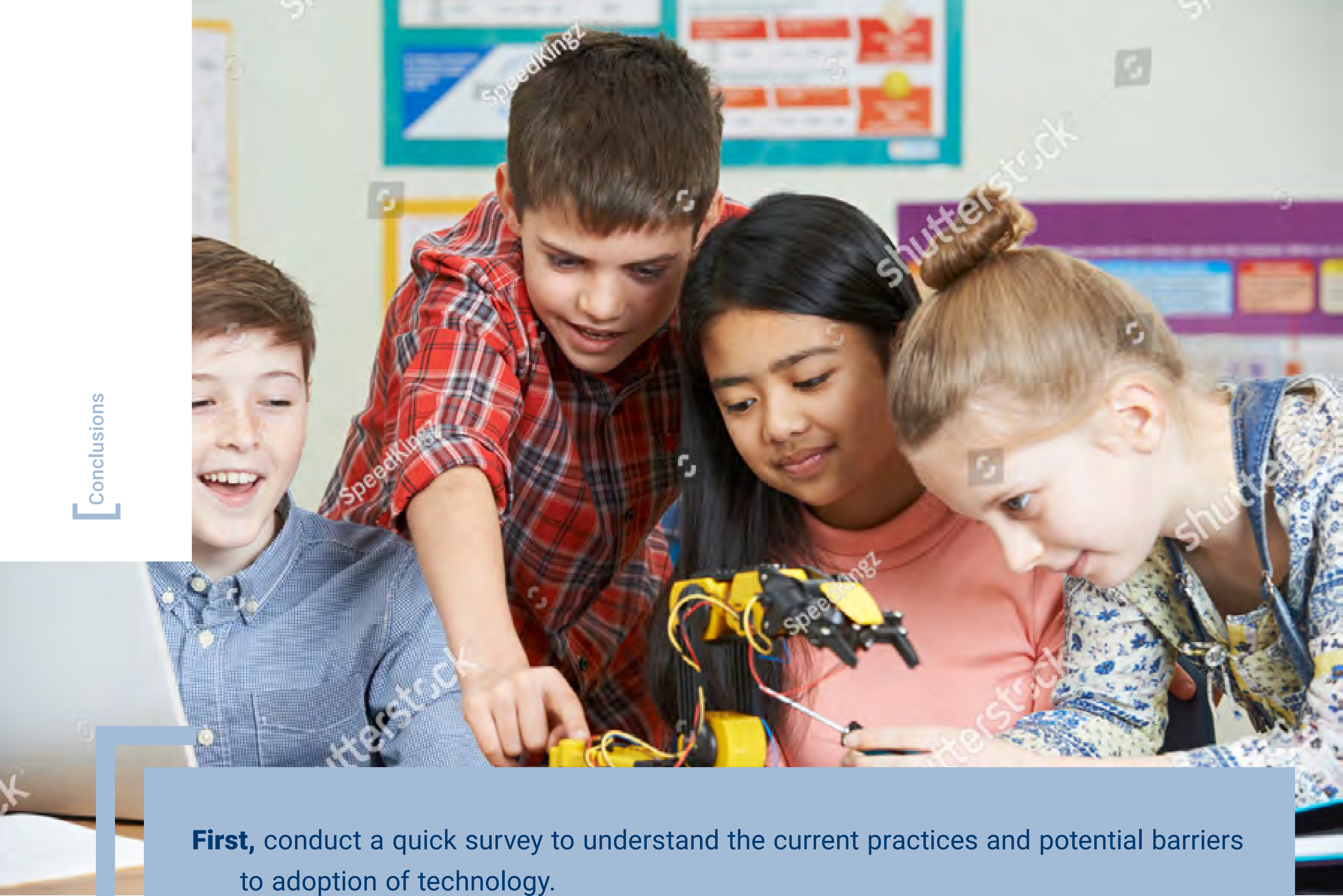
2. Facilitating differentiated instruction – through, for example, computer-adaptive learning and live one-on-one tutoring;

3. Expanding opportunities to practice; and

4. Increasing student engagement – through videos and games.

Our review of the evidence and our own experiences analyzing school systems across the world leads us to conclude that there is no single "ed-tech" initiative that will achieve the same results everywhere, simply because school systems differ in students and teachers, as well as in the availability and quality of materials and technologies. Instead, to realize the potential of education technology to accelerate student learning, a first important step is to understand how technology is being used given the specific contexts and needs of students, teachers, and parents. To this end, we discussed the rationale for applying a set of surveys to collect information from students, teachers, and school leaders that may guide decisionmakers in expanding the use of technology for learning. The detailed surveys are included in **Appendix A**.

Our goal is to provide concrete guidance to education authorities intent on leapfrogging learning inequality. In a nutshell, a summary of our five key recommendations (described in more detail in the previous section) follow.



First, conduct a quick survey to understand the current practices and potential barriers to adoption of technology.

Second, consider how the introduction of technology may affect the interactions among students, teachers, and content.

Third, define clear objectives for the education technology and establish ways to regularly assess progress and make course corrections in a timely manner.

Fourth, understand that *how* this kind of reform is approached can matter immensely for its success. It is vital that technology be adopted with the input of educators and families and with attention to how it will be used.

Finally, communicate with a range of stakeholders, including teachers, school leaders, parents, and students. Deliberately and consistently explain what technology is and is not supposed to do, how it can be most effectively used, and the ways in which it can help can make it more likely that programs work as intended.

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Appendix A: Instruments to assess availability and use of technology for learning

A1: Student survey

Section A: Access to technology

1 **Are any of the following available at your home and/or school?** *[Select all that apply.]* Source: PISA 2018; Question(s): IC001Q01TA-IC001Q11TA and IC009Q01TA- IC009Q11TA [adapted]

	AT HOME	AT SCHOOL
a) Desktop computer	☐	☐
b) Laptop or notebook	☐	☐
c) Tablet (e.g., iPad)	☐	☐
d) Games console (e.g., PlayStation)	☐	☐
e) Printer	☐	☐
f) e-Reader (e.g., Kindle)	☐	☐
g) Internet	☐	☐

2 **Do you own a cell phone?** *[Select all that apply.]* Source: PISA 2018; Question(s): IC001Q01TA-IC001Q11TA and IC009Q01TA-IC009Q11TA [adapted]

a) Yes, without Internet and data
b) Yes, with Internet (but no data)
c) Yes, with data (but no Internet)
d) Yes, with Internet and data

Section B: Use of technology

3 **During the past week (from last Monday to last Friday), for how long did you use the following AT SCHOOL?** *[Select one option per row.]* Source: PISA 2018; Question(s): IC005Q01TA01-IC005Q01TA07

	NO TIME	1-30 MINUTES PER DAY	31-60 MINUTES PER DAY	1-2 HOURS PER DAY	2-4 HOURS PER DAY	4 HOURS OR MORE PER DAY
a) Desktop computer	☐	☐	☐	☐	☐	☐
b) Laptop or notebook	☐	☐	☐	☐	☐	☐
c) Tablet (e.g., iPad)	☐	☐	☐	☐	☐	☐
d) Internet	☐	☐	☐	☐	☐	☐

4 **During the past week (from last Monday to last Friday), in which subject(s) did you use a desktop computer, laptop, or tablet AT SCHOOL?** *[Select all that apply.]* Source: PISA 2018; Question(s): IC151Q01HA-IC151Q09HA [adapted]

	I DO NOT STUDY THIS SUBJECT	NEITHER THE TEACHER NOR THE STUDENTS	ONLY THE TEACHER	ONLY THE STUDENTS	BOTH THE TEACHER AND THE STUDENTS
a) Language	☐	☐	☐	☐	☐
b) Math	☐	☐	☐	☐	☐
c) Natural sciences	☐	☐	☐	☐	☐
d) Social sciences	☐	☐	☐	☐	☐
e) Music	☐	☐	☐	☐	☐
f) Sports	☐	☐	☐	☐	☐
g) Foreign language	☐	☐	☐	☐	☐

5 **During the past week (from last Monday to last Friday), in which subject(s) did you use a desktop computer, laptop, or tablet OUTSIDE OF SCHOOL?** *[Select all that apply.]* Source: PISA 2018; Question(s): IC151Q01HA-IC151Q09HA [adapted]

	I DO NOT STUDY THIS SUBJECT	NEITHER THE TEACHER NOR THE STUDENTS	ONLY THE TEACHER	ONLY THE STUDENTS	BOTH THE TEACHER AND THE STUDENTS
a) Language	☐	☐	☐	☐	☐
b) Math	☐	☐	☐	☐	☐
c) Natural sciences	☐	☐	☐	☐	☐
d) Social sciences	☐	☐	☐	☐	☐
e) Music	☐	☐	☐	☐	☐
f) Sports	☐	☐	☐	☐	☐
g) Foreign language	☐	☐	☐	☐	☐

6 **During the past week (from last Monday to last Friday), for how long did you use the following OUTSIDE OF SCHOOL?** *[Select one option per row.]* Source: PISA 2018; Question(s): IC006Q01TA01-IC006Q01TA07

	NO TIME	1-30 MINUTES PER DAY	31-60 MINUTES PER DAY	1-2 HOURS PER DAY	2-4 HOURS PER DAY	4 HOURS OR MORE PER DAY
a) Desktop computer	☐	☐	☐	☐	☐	☐
b) Laptop or notebook	☐	☐	☐	☐	☐	☐
c) Tablet (e.g., iPad)	☐	☐	☐	☐	☐	☐
d) Internet	☐	☐	☐	☐	☐	☐

7 **During the past weekend (from last Saturday to last Sunday), for how long did you use the following OUTSIDE OF SCHOOL?** *[Select one option per row.]* Source: PISA 2018; Question(s): IC007Q01TA01-IC007Q01TA07

	NO TIME	1-30 MINUTES PER DAY	31-60 MINUTES PER DAY	1-2 HOURS PER DAY	2-4 HOURS PER DAY	4 HOURS OR MORE PER DAY
a) Desktop computer	☐	☐	☐	☐	☐	☐
b) Laptop or notebook	☐	☐	☐	☐	☐	☐
c) Tablet (e.g., iPad)	☐	☐	☐	☐	☐	☐
d) Internet	☐	☐	☐	☐	☐	☐

8 **How often do you use any of the following?** *[Select one option per row.]* Source: PISA 2003; Question(s): IC05Q01-IC05Q12 [adapted]

	ALMOST EVERY DAY	A FEW TIMES A WEEK	BETWEEN ONCE A WEEK AND ONCE A MONTH	LESS THAN ONCE A MONTH	NEVER
a) The Internet	☐	☐	☐	☐	☐
b) Word processing software (e.g., Microsoft Word)	☐	☐	☐	☐	☐
c) Spreadsheets (e.g., Microsoft Excel)	☐	☐	☐	☐	☐
d) Educational software (e.g., encyclopedia)	☐	☐	☐	☐	☐
e) Games software, website, or platform	☐	☐	☐	☐	☐
f) Music player (e.g., Spotify, Apple Music)	☐	☐	☐	☐	☐
g) E-mail (e.g., Gmail, Microsoft Outlook)	☐	☐	☐	☐	☐

h)	Video streaming platforms (e.g., Netflix, YouTube)	☐	☐	☐	☐	☐
i)	Programming/coding software (e.g., Python)	☐	☐	☐	☐	☐

9 **Do you use the Internet for any of the following SCHOOL RELATED purposes?**
[Select all that apply.] Source: TIMSS; Question(s): Student survey, Q14 [adapted]

a) Access the textbook or other course materials.
b) Access assignments posted online by my teacher.
c) Collaborate with classmates on assignments or projects.
d) Communicate with the teacher.
e) Find information, articles, or tutorials to aid in understanding of academic subjects (e.g., math, language, natural and social sciences).

Section C: Purposes for technology

10 **How often do you use the Internet for any of the following purposes?** *[Select all that apply.]* Source: PISA 2003; Question(s): IC05Q01-IC05Q12 [adapted]

	ALMOST EVERY DAY	A FEW TIMES A WEEK	BETWEEN ONCE A WEEK AND ONCE A MONTH	LESS THAN ONCE A MONTH	NEVER
a) Look up information about people, things, or ideas (e.g., Google)	☐	☐	☐	☐	☐
b) Download software	☐	☐	☐	☐	☐
c) Collaborate with others on a project	☐	☐	☐	☐	☐
d) Play games	☐	☐	☐	☐	☐
e) Play videos	☐	☐	☐	☐	☐
f) Play music	☐	☐	☐	☐	☐
g) Social media (e.g., Facebook, Instagram)	☐	☐	☐	☐	☐

Section D: Experience and ease of use

11 **How old were you when you first used the following?** *[Select one option per row.]* Source: PISA 2018; Question(s): IC002Q01HA06-IC002Q01NA05 [adapted]

	NEVER	3 YEARS OLD OR YOUNGER	4-6 YEARS OLD	7-9 YEARS OLD	10-12 YEARS OLD	13 YEARS OR OLDER
a) Desktop computer	☐	☐	☐	☐	☐	☐
b) Laptop or notebook	☐	☐	☐	☐	☐	☐
c) Tablet (e.g., iPad)	☐	☐	☐	☐	☐	☐
d) Internet	☐	☐	☐	☐	☐	☐

12 **How well can you do each of the following tasks on a computer?** *[Select all that apply.]* Source: PISA 2003; Question(s): IC06Q01-IC06Q23 [adapted]

	I CAN DO THIS BY MYSELF	I CAN DO THIS WITH HELP FROM SOMEONE	I KNOW WHAT IT MEANS BUT CANNOT DO IT	I DON'T KNOW WHAT IT MEANS
a) Open a program	☐	☐	☐	☐
b) Open a file	☐	☐	☐	☐
c) Create a new file	☐	☐	☐	☐
d) Copy-paste a file	☐	☐	☐	☐
e) Copy-paste text	☐	☐	☐	☐
f) Print a file	☐	☐	☐	☐
g) Save a file	☐	☐	☐	☐

13 **Have you done any of the following to find out about future study or types of work?** *[Select all that apply.]* Source: PISA 2018; Question(s): EC150Q01WA-EC150Q10WA [adapted]

	YES	NO, NEVER
a) I researched the Internet for information about colleges	☐	☐
b) I researched the Internet for information about jobs	☐	☐

A2: Teacher survey

Section A: Access to technology

1 **Are any of the following available at your school, classroom, and/or home?** *[Select all that apply.]* Source: PISA 2018; Question(s): IC001Q01TA-IC001Q11TA and IC009Q01TA- IC009Q11TA [adapted]

		IN MY SCHOOL	IN MY CLASSROOM	IN MY HOME
a)	a. Desktop computer	☐	☐	☐
b)	b. Laptop or notebook	☐	☐	☐
c)	c. Tablet (e.g., iPad)	☐	☐	☐
d)	d. Printer	☐	☐	☐
e)	e. e-Reader (e.g., Kindle)	☐	☐	☐
f)	f. Internet	☐	☐	☐

2 **Do you own a cell phone?** *[Select all that apply.]* Source: PISA 2018; Question(s): IC001Q01TA-IC001Q11TA and IC009Q01TA-IC009Q11TA [adapted]

a) Yes, without Internet and data
b) Yes, with Internet (but no data)
c) Yes, with data (but no Internet)
d) Yes, with Internet and data

3 **Do the students in your class have access to computers (desktop or laptop)?** *[Select one option per row.]* Source: TIMSS 2015; Question(s): TC169Q01HA-TC169Q14HA [adapted]

		YES	NO
a)	Each student has a computer	☐	☐
b)	The class has computers that students can share	☐	☐
c)	The school has computers that the class can use sometimes	☐	☐

Section B: Use of technology

4 **How often are you involved in the following activities?** *[Select one option per row.]* Source: PISA 2018; Question(s): TC176Q01HA-TC176Q07HA [adapted]

	I DON'T KNOW WHAT IT IS	NEVER OR ALMOST NEVER	SEVERAL TIMES A MONTH	SEVERAL TIMES A WEEK	SEVERAL TIMES A DAY
a) Exchanging e-mails	☐	☐	☐	☐	☐
b) Exchanging messages (e.g., SMS, WhatsApp)	☐	☐	☐	☐	☐
c) Reading online news	☐	☐	☐	☐	☐
d) Searching information online to learn about a topic	☐	☐	☐	☐	☐
e) Taking part in online group discussions	☐	☐	☐	☐	☐
f) Searching practical information online (e.g., schedules, events)	☐	☐	☐	☐	☐

Section C: Purposes for technology

5 **During the last month, did you ask your students to use digital devices (desktop computers, laptops or notebooks, tablets, or cell phones) for any of the following purposes?** *[Select one option per row.]* Source: PISA 2018; Question(s): TC168Q01HA- TC168Q12HA [adapted]

	YES	NO
a) Searching for subject-related information online	☐	☐
a) Working on extended projects (i.e., over several weeks)	☐	☐
b) Working on short assignments (i.e., within a week)	☐	☐
c) Working at their individual pace	☐	☐
d) Working on individualized material	☐	☐
e) Planning a sequence of learning activities for themselves	☐	☐
f) Submitting homework or classwork	☐	☐
g) Practicing or drilling	☐	☐
h) Coordinating schoolwork with other students	☐	☐
i) Following up on missed lessons or material	☐	☐
j) Reading texts electronically instead of paper versions	☐	☐
k) Writing a text such as a blog or wiki	☐	☐

6 **How often did you use the following tools in your teaching this school year?** *[Select one option per row.]* Source: PISA 2018; Question(s): TC169Q01HA- TC169Q14HA [adapted]

	NEVER	IN SOME LESSONS	IN MOST LESSONS	IN EVERY OR ALMOST EVERY LESSON
a) Tutorial software or practice program	☐	☐	☐	☐
b) Digital learning games	☐	☐	☐	☐
c) Word-processing software (e.g., Microsoft Word)	☐	☐	☐	☐

d)	Presentation software (e.g., Microsoft PowerPoint)	☐	☐	☐	☐
e)	Spreadsheets (e.g., Microsoft Excel)	☐	☐	☐	☐
f)	Multimedia production tools	☐	☐	☐	☐
g)	Social media (e.g., Facebook, Instagram)	☐	☐	☐	☐
h)	Communications (e.g., e-mail, blogs)	☐	☐	☐	☐
i)	Computer-based information resources (e.g., websites, wikis, encyclopedia)	☐	☐	☐	☐
j)	Graphing or drawing software	☐	☐	☐	☐
k)	Software for assessing student learning	☐	☐	☐	☐

7 **In your lessons, have you taught any of the following?** *[Select one option per row.]* Source: PISA 2018; Question(s): TC166Q01HA-TC166Q07HA [adapted]

		YES	NO
a)	How to use keywords when using a search engine (e.g., Google)	☐	☐
b)	How to decide whether to trust information from the Internet	☐	☐
c)	How to compare different web pages and decide what information is more relevant for students' work	☐	☐
d)	To understand the consequences of making information publicly available on social media (e.g., Facebook, Instagram)	☐	☐
e)	How to use the short description below the links in the list of results of a search	☐	☐
f)	How to detect whether the information is subjective or biased	☐	☐
g)	How to detect phishing or spam e-mails	☐	☐

Section D: Experience and ease of use

8 **In the past year, have you participated in professional development in integrating information technology into instruction?** *[Select one option.]* Source: TIMSS 2015; Question(s): Teacher survey, Q24-Q25 [adapted]

a) No
b) Yes, for less than 6 hours
c) Yes, for 6-15 hours
d) Yes, for 16-35 hours
e) Yes, for more than 35 hours

9 **To what degree do you need further professional development in integrating information technology into instruction?** *[Select one option.]* Source: PISA 2018; Question(s): TC185Q05HA [adapted]

a) No need at present
b) Low level of need
c) Moderate level of need
d) High level of need

Section E: Challenges to technology adoption

10 **In your current school, how severe is each of the following problems?** *[Select one option per row.]* Source: TIMSS 2015; Question(s): Teacher survey, Q8 [adapted]

	NOT A PROBLEM	MINOR PROBLEM	MODERATE PROBLEM	SERIOUS PROBLEM
a) Computers need significant repair	☐	☐	☐	☐
b) Teachers do not have a space to use computers	☐	☐	☐	☐
c) Students do not have a space to use computers	☐	☐	☐	☐
d) Software installed is outdated	☐	☐	☐	☐
e) Internet access is unreliable	☐	☐	☐	☐

A3: Principal survey

Section A: Access to technology

1 **Are any of the following available at your home and/or school?** *[Select all that apply.]* Source: PISA 2018; Question(s): IC001Q01TA-IC001Q11TA and IC009Q01TA- IC009Q11TA [adapted]

	IN MY HOME	IN MY CHOOL
a) Desktop computer	☐	☐
b) Laptop or notebook	☐	☐
c) Tablet (e.g., iPad)	☐	☐
d) Printer	☐	☐
e) e-Reader (e.g., Kindle)	☐	☐
f) Internet	☐	☐

2 **Do you own a cell phone?** *[Select all that apply.]* Source: PISA 2018; Question(s): IC001Q01TA-IC001Q11TA and IC009Q01TA-IC009Q11TA [adapted]

a) Yes, without Internet and data
b) Yes, with Internet (but no data)
c) Yes, with data (but no Internet)
d) Yes, with Internet and data

3 **The goal of the following set of questions is to gather information about the student-computer ratio for students in grade 10 at your school.***[Enter a number for each response. Enter "0" (zero) if there are none.]* Source: PISA 2018; Question(s): SC004Q01TA- SC004Q07TA [adapted]

	NUMBER
a) At your school, what is the total number of students in grade 10?	
b) Approximately, how many desktop computers are available for these students for educational purposes?	
c) Approximately, how many of these computers are connected to the Internet?	
d) Approximately, how many laptop computers or notebooks are available for these students for educational purposes?	
e) Approximately, how many tablets are available for these students for educational purposes?	
f) Approximately, how many interactive whiteboards are available in this school altogether?	
g) Approximately, how many data projectors are available in the school altogether?	
h) Approximately, how many computers with internet connection are available for teachers in your school?	

Section B: Challenges to technology adoption

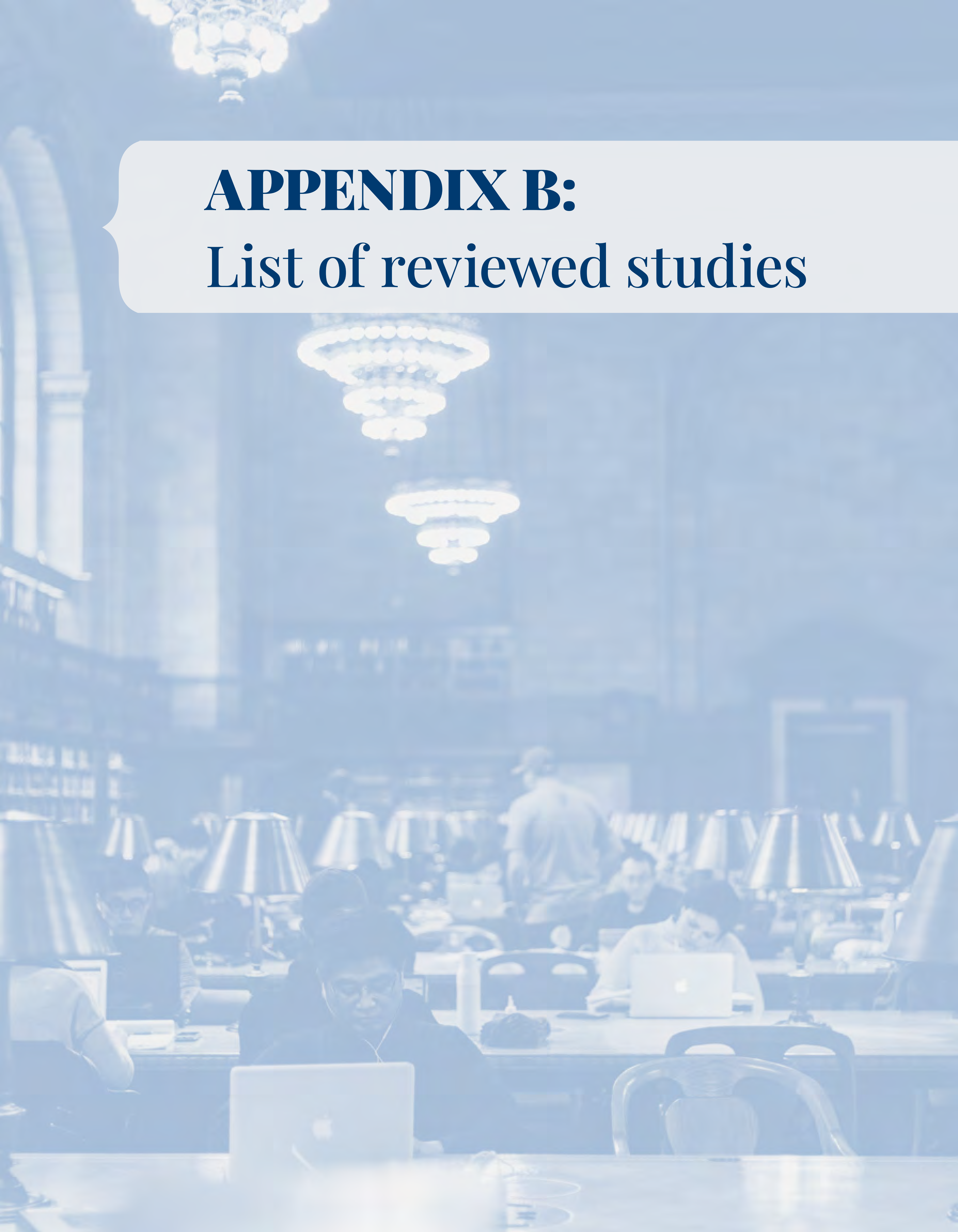
4 **To what extent do you agree with the following statements about your school's capacity to enhance learning and teaching using digital devices?**
[Select one option per row.] Source: PISA 2018; Question(s): SC155Q01HA-SC155Q11HA [adapted]

	STRONGLY DISAGREE	DISAGREE	AGREE	STRONGLY AGREE
a) The number of digital devices connected to the Internet is insufficient	☐	☐	☐	☐
b) The school's Internet bandwidth or speed is insufficient	☐	☐	☐	☐
c) The number of digital devices for instruction is sufficient	☐	☐	☐	☐
d) Digital devices at the school have sufficient computing capacity	☐	☐	☐	☐
e) The availability of adequate software is sufficient	☐	☐	☐	☐
f) Teachers have the necessary technical and pedagogical skills to integrate digital devices in instruction	☐	☐	☐	☐
g) Teachers have sufficient time to prepare lessons integrating digital devices	☐	☐	☐	☐
h) Effective professional resources for teachers to learn how to use digital devices are available	☐	☐	☐	☐
i) Teachers are provided with incentives to integrate digital devices in their teaching	☐	☐	☐	☐
j) The school has sufficient qualified technical assistant staff	☐	☐	☐	☐

5 **Does your school have any of the following?** *[Select one option per row.]*
Source: PISA 2018; Question(s): SC156Q01HA-SC156Q08HA [adapted]

		YES	NO
a)	Its own written statement about the use of digital devices	☐	☐
b)	Its own written statement specifically about the use of digital devices for pedagogical purposes	☐	☐
c)	A program to use digital devices for teaching and learning in specific subjects	☐	☐
d)	Regular discussions with teaching staff about the use of digital devices for pedagogical purposes	☐	☐
e)	A specific program to prepare students for responsible Internet behavior	☐	☐
f)	A specific policy about using social networks (e.g., Facebook) in teaching and learning	☐	☐
g)	A specific program to promote collaboration on the use of digital devices among teachers	☐	☐
h)	h. Scheduled time for teachers to meet to share, evaluate or develop instructional materials and approaches that employ digital devices	☐	☐

APPENDIX B:
List of reviewed studies



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New evidence on classroom computers and pupil learning
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Economic Journal
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2019
Does gamification in education work?: Experimental evidence from Chile
Working paper
https://publications.iadb.org/en/does-gamification-education-work-experimental-evidence-chile-0
Chile

3. **Bando, R.; Gallego, F.; Gertler, P. J.; Romero, D**
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Books or laptops? The cost-effectiveness of shifting from printed to digital delivery of educational content
Working paper
http://www.nber.org/papers/w22928.pdf
Honduras

4. **Banerjee, A. V.; Cole, S.; Duflo, E.; Linden, L. L.**
2007
Remedying education: Evidence from two randomized experiments in India
Journal article
The Quarterly Journal of Economics
http://qje.oxfordjournals.org/content/122/3/1235.full.pdf+html
India

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2009
The use and misuse of computers in education: Evidence from a randomized experiment in Colombia
Working paper
http://documents.worldbank.org/curated/en/346301468022433230/pdf/WPS4836.pdf
Colombia

6. **Beg, S. A.; Lucas, A. M.; Halim, W.; Saif, U.**
2020
Beyond the basics: Improving post-primary content delivery through classroom technology
Working paper
Pakistan

7. **Berlinski, S.; Busso, M.**
2013
Pedagogical change in mathematics teaching: Evidence from a randomized control trial
Unpublished manuscript
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Costa Rica

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2015
One Laptop per Child at Home: Short-Term Impacts from a Randomized Experiment in Peru
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https://www.aeaweb.org/articles?id=10.1257/app.20130267
Peru

9. **Büchel, K.; Jakob, M.; Kühnhanss, C.; Steffen, D.; Brunetti, A.**
2020
The relative effectiveness of teachers and learning software: Evidence from a field experiment in El Salvador
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2011
Information technology and student achievement: Evidence from a randomized experiment in Ecuador
Working paper
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Ecuador

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2020
Does online tutoring work? Evidence from a cross-cultural tutoring experiment between Canada and Kenya
Unpublished manuscript
Kenya

12. **Chiplunkar, G.; Dhar, D.; Nagesh, R.**
2020
Too little, too late: Improving post-primary learning outcomes in India
Working paper
https://urldefense.proofpoint.com/v2/url?u=https-3A__riseprogramme.org_sites_default_files_inline-2Dfiles_Dhar.pdf&d=DwMFaQ&c=slrrB7dE8n7gBJbeOog-IQ&r=lFHfNpFB8qA6XTulbdqAhovWwVuox7Ruofv3AZVxgVo&m=UeiNQdyrC2Mlu5f9lWp-3EGAuj_jzQwXiF8Wx6MHPAs&s=FtKsLm2w1pwv14Ez FBIcwsUQe8rJ9UfPdd5ddjYLbsY&e=
India

13. **Cristia, J.; Ibarrarán, P.; Cueto, S.; Santiago, A.; Severín, E.**
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Technology and child development: Evidence from the One Laptop per Child program
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14. **de Barros, A.**
2020
Do students benefit from blended instruction? Experimental evidence from public schools in India
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15. **de Hoop, T.; Ring, H.; Siwach, G.; Dias, P.; Tembo, G.; Rothbard, V.; Toungui, A.**
2020
Impact of e-learning technology and activity-based learning on learning outcomes: Experimental evidence from community schools in rural Zambia
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Mexico

17. **Ferman, B.; Finamor, L.; Lima, L.**
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Are public schools ready to integrate math classes with Khan Academy?
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Computer technology in education: Evidence from a pooled study of computer assisted learning programs among rural students in China
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20. **Johnston, J.; Ksoll, C.**
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Does computer-assisted learning improve learning outcomes? Evidence from a randomized experiment in migrant schools in Beijing
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Isolating the "tech" from edtech: Experimental evidence on computer assisted learning in China
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China

Appendix C:
How may technology affect interactions among students, teachers, and content?

Our review of the evidence indicates that technology may accelerate student learning only when it affects the interactions among students, content, and teachers in meaningful ways, such as when it is used to scale up access to quality content, facilitate differentiated instruction, increase opportunities for practice, or increase student engagement. In this Appendix, to provide more practical information, we highlight some questions for decisionmakers to ask before investing in education technology.

When considering investing in deploying devices to classrooms:

- *Will the device(s) supplant an analog version while teacher practices and student engagement with the material remain unchanged?*
- *Are teachers familiar with the device(s) and its potential comparative advantages for teaching and learning?*
- *Are teacher training and professional development programs in place to help teachers play to the device(s)' comparative advantages for teaching and learning?*
- *How will you know if the device(s) are successful in accelerating teaching and learning? (i.e., do you have clear objectives and metrics to measure progress?)*

When considering investing in new platforms/ software programs:

- *Is the platform/software program intuitive to use and engaging (for both teachers and students)?*
- *Does the platform/software program's contents align with the education system's curricular goals?*
- *Does the platform/software program's contents offer new and varied tools for students to engage with content (e.g., practice exercises, videos, and games)?*
- *Does the platform/software program have the built-in capacity to adjust contents based on students' input (i.e., can it provide personalized learning opportunities)?*
- *How will you know if the platform/software program(s) is(are) successful in accelerating teaching and learning? (i.e., do you have clear objectives and metrics to measure progress?)*