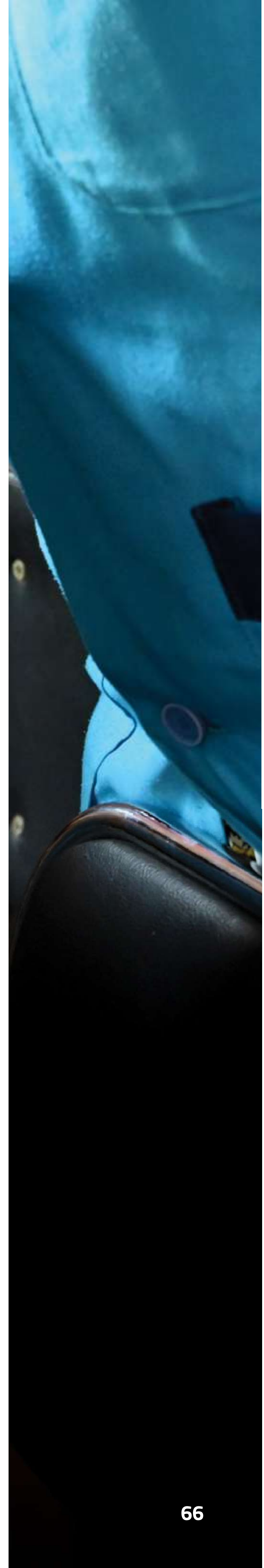
CHAPTER

4



Teaching and learning

KEY MESSAGES

Technology can facilitate teaching and learning processes but requires contextualization and integrated support.

Technology offers many potential benefits for teaching and learning but the evidence has major limitations.

- Systematic reviews of the past two decades find a small to medium positive effect of education technology on learning outcomes.
- But evaluations of what works are limited in geographical, subject and durational scope, and can often obscure the role of various pedagogical factors in influencing outcomes.
- Technology companies can have disproportionate influence. Pearson funded its own studies, contesting independent analysis showing no impact.

Technology does not need to be advanced to have an impact; it needs to be context specific.

- Pre-recorded lessons can reduce urban–rural teaching quality divides. In China, high-quality lesson recordings were delivered to 100 million rural students, improving student outcomes by 32% and reducing urban–rural earning gaps by 38%.
- Devices with pre-loaded content need contextualization and integration support. In Peru, the One Laptop Per Child programme distributed over 1 million laptops without any positive impact on learning.

Technology can improve instruction quality by adding time and personalization.

- Personalization software can monitor student progress and provide differentiated practice opportunities and feedback. Evaluations of the Ei Mindspark software in India documented learning gains in after-school settings and for low-performing students.

Digital technology improves student engagement, with appropriate pedagogical integration.

- Digital game-based applications improved cognitive and behavioural outcomes in primary and secondary mathematics in 43 studies published in 2008–19.
- Interactive whiteboards can potentially support the visual, auditory and tactile experiences of teaching and learning if well integrated. But in the United Kingdom, large-scale adoption was limited to uses such as blackboard replacement.
- Augmented and virtual reality technology can supplement practical training in science and vocational lessons.

Digital technology can facilitate regular parental communication to support children's learning.

- Sending caregivers regular nudges can positively influence learning outcomes. During COVID-19, Botswana's education ministry provided parents with over-the-phone tutoring for numeracy concepts, leading to learning outcome improvements.

ICT use carries a risk of increasing distraction and lowering student engagement.

- Technology use beyond a moderate threshold was associated with diminishing academic gains in an analysis of 2018 Programme for International Student Assessment data.
- A meta-analysis of research in 2008–17 across 14 countries found a negative effect of mobile phones on academic performance.
- COVID-19 online learning adversely affected younger learners. In Switzerland, secondary school children sustained their learning progress better than primary schoolgoers in online learning.

Because digital technology impacts so many aspects of daily life, it is a reasonable assumption that its application in the classroom will automatically transform and improve teaching and learning. However, while students need to be taught about digital technology, as part of what is called 'digital literacy' **(Chapter 5)**, this does not necessarily mean that students need to be taught through digital technology. The value of digital technology for teaching and learning needs to be proven. The ways in which technology has been used over time to support teaching and learning continue to evolve, alongside a better understanding of how technology should be used.

This chapter focuses on how technology is being used to support teaching and learning. First, it presents the potential of and challenges posed by technology integration and describes key trends in technology use. Second, it reviews the evidence on the possible benefits of digital technologies for improving education quality, grouping them into two broad categories: those that directly focus on improving the quality of instruction, by distributing resources more equitably, personalizing and increasing practice opportunities; and those that seek to better engage learners.

"While students need to be taught about digital technology, this does not mean that students need to be taught through digital technology"

TECHNOLOGY'S POTENTIAL FOR TEACHING NEEDS TO BE SHOWN IN PRACTICE

Views about how people learn have evolved considerably over the past 100 years. The earliest theories, known as behaviourism, saw learning as a process of receiving and accumulating knowledge in a programmed manner. The emphasis gradually shifted. Some theories, notably constructivism, recognized that individual learners 'construct' their knowledge through inquiry and experimentation. Others complemented this view with a sociocultural perspective, which recognizes that learning is enhanced through collaboration and support. In the digital era, a newer approach, described as connectivism, has drawn attention to the importance of learning through forming connections around information (Selwyn, 2022). Each theory helps explain the opportunities and limits of technology to mediate various kinds of learning.

There are two broad types of possibilities that technology offers for teaching and learning. First, technologies can improve the quality of instruction by redistributing resources, increasing chances to practise, supplementing instructional time and personalizing instruction (Escueta et al., 2020; Ganimian et al., 2020; Major et al., 2021). Second, technologies can engage and support learners by varying how content is represented, stimulating interaction and prompting collaboration (**Figure 4.1**).

TABLE 4.1:
Affordances of technology use in teaching and learning

Improve instructional quality	Engage and support learners
Pre-recorded or broadcast lessons Hardware preloaded with content Drill and practice software Software to supplement instructional time Personalized and adaptive software	Interactive whiteboards Digital games Simulations Collaborative digital tools ICT for communication with parents

Sources: GEM Report, adapted from Bulger (2016); Burns (2021); Escueta et al. (2020); Ganimian et al. (2020); Major and Francis (2020); Selwyn (2022); Topping et al. (2022).

Technology used in various combinations can achieve multiple objectives. Data and learning analytics can guide and customize learning experiences, whether they simply respond to learners or actively try to guide them adaptively (Bulger, 2016). Feedback can be more immediate and more accurate. Personalized tools can propose tailored content and activities (OECD, 2019). Students could spend less time in face-to-face and whole classroom instruction. Hybrid models of in-person and remote education could provide learners with materials to work from wherever they are, whenever they can. Self-paced and supplemented learning could help struggling learners (Duraiappah et al., 2021), even though information and communication technology (ICT) can distract learners and be used for leisure instead of study. Teachers can develop lessons for students to learn at their own pace through personalized and adaptive software, freeing up time for them to coach individual students or work with small groups (Bulman and Fairlie, 2016; Reich, 2020). Technology can be used to help prepare and deliver engaging lessons through such tools as interactive whiteboards in smart classrooms, simulations and collaborative learning. Cognitive load, i.e. how much information can be held in the working memory at the same time, can be reduced and student motivation increased if materials are presented using multimedia or digital games (Jamshidifarsani et al., 2019).

In high-income countries, some teachers report that technology-based tools improve learning. According to the 2018 International Computer and Information Literacy Study (ICILS), 87% of teachers in 12 participating education systems thought that ICT helped students work at a level appropriate to their learning needs and 78% that ICT enabled students to collaborate more effectively (Fraillon et al., 2019). In the United States, a 2019/20 survey found that about a third of public school representatives strongly agreed that technology use in the classroom helped students learn more in an independent and self-directed way, at their own pace, and collaboratively with peers. About half stated that teachers used technology to a moderate or large extent for classroom work that would not have been possible without it (Gray and Lewis, 2021). In Australia, a teacher survey of technology use in mathematics classrooms highlighted easier visualizations of mathematical concepts and student opportunities to work at their own pace and academic ability level (Attard and Holmes, 2022).

However, the fact that technology has the potential to support education systems does not necessarily mean that teaching processes and practices have been substantially transformed (Reich, 2020). Some who promote technology use in classrooms are accused of seeing technology as a solution to every education problem. But technology may not be the right approach to address contextual and systemic challenges that prevent learners from acquiring basic skills. Altering pedagogical practices in fundamental ways exerts pressure on teachers, staff, students, parents and caregivers who may be unprepared to deal with them or may disagree with the consequences. And far from being learner-centred, technology may promote a highly individualistic approach to gaining knowledge that undermines the collaboration and civic engagement that are needed in public institutions (Selwyn, 2022).

Embedding technology into learning processes has risks of its own. It can narrow learning priorities to those areas served best by the most marketed and accessible technological products. A large review of research focusing on the effectiveness of online and blended learning in schools found that many studies failed to report on all pedagogical elements, suggesting authors were 'digital enthusiasts who were less enthusiastic about pedagogy' (Topping et al., 2022). Moreover, the content of learning applications may not be focused on learning objectives. In the United Kingdom, a quarter of all commercial applications labelled as educational on the Google Play Store (Kanders et al., 2022) and the same share of the most popular mathematics applications in both the Apple and Google Play Stores (Outhwaite et al., 2022a) did not include any explicit learning content.

Technology companies can have disproportionate influence. With tremendous incentives to show effectiveness, they may present only evidence that supports them. While independent evaluations of Successmaker, a reading and mathematics instruction tool, found negative or null effects on learning in the United States, Pearson – the company that developed the product – continues to publicize self-funded findings and conclusions of significant, positive effects (Mathewson and Butrymowicz, 2020).

> Technology companies may present only evidence that supports them

Key commercial actors act as both salespeople and advisors at the same time. Analysis of the networks and channels of influence in technology in Norway showed a direct link between industry, through the New Media Consortium, an international community of education technology actors, and the government, through the Centre for ICT in Education under the authority of the Ministry of Education and Research (Haugsbakk, 2021). In the Netherlands, international actors have become increasingly important in education technology. Google has an estimated 70% market share in primary education technology (Kerssens and van Dijck, 2021). Intel is implementing artificial intelligence (AI) curricula in India for 22,000 schools with the Central Board for Secondary Education; in Poland, where the national AI curriculum is based on Intel's AI for Youth programme; and in the Republic of Korea, where the Ministry of Education has signed a memorandum of understanding to also scale AI for Youth (Intel Corporation, 2022).

TECHNOLOGY IS NOT USED VERY EXTENSIVELY FOR TEACHING AND LEARNING

Learning achievement surveys show that the prevalence of ICT usage in classrooms is not particularly high, even in the world's richest countries. According to the 2018 Programme for International Student Assessment (PISA), only about 10% of 15-year-old students in over 50 participating education systems used digital devices on average for more than one hour per week in mathematics and science lessons. Denmark was an outlier as the only country where more than half of students reported such use in both subjects. The next highest were Australia and Sweden (**Figure 4.1a**), with about one in three students in both countries reporting such use in science, but less in mathematics. The survey also collected information on the frequency with which students use digital devices at school for different purposes. For instance, just over one third of 15-year-olds reported using such devices at least once or twice per week for drills and practice.

According to the 2019 Trends in International Mathematics and Science Study (TIMSS), fewer than one in four students on average attended schools where science teachers carried out computer activities at least once or twice a week. The average prevalence did not increase between grades 4 and 8. More than two in three students were in schools that included computer activities in grade 8 science classes in Australia, New Zealand and the United States. By contrast, fewer than 5% of students attended such schools in Cyprus and France (Mullis et al., 2020) (**Figure 4.1b**).

The 2018 ICILS showed that considerable ICT resources were available in the 12 participating education systems, all but one from high-income countries. About 60% of grade 8 students – but 83% in Uruguay and over 90% in Denmark and Finland – studied in schools whose ICT coordinators reported there were practice programmes or applications. Single- or multi-user games were available to 5 in 10 and 3 in 10 students, respectively. Simulation and modelling software for classroom use were available for 42% of students, but this number ranged from 8% in Italy to 91% in Finland (Fraillon et al., 2019) (**Figure 4.2**).

Academic and market research sources provide complementary evidence on the characteristics of education technology products while not always clearly distinguishing whether they are also being used in classrooms. A global mapping of over 300 education technology products found that two thirds of them focused on student-led self-learning, lesson delivery and lesson preparation (Central Square Foundation, 2021). Analysis in Pakistan looked at 48 digital learning tools from 17 organizations, the fastest growing of which were active in profitable areas, such as examination preparation (Zubairi et al., 2022). An in-depth mapping of 50 digital learning platforms and tools in Latin America found that 14 tools used personalization to adapt to student learning levels, 12 used AI or machine learning, and 21 used gamification or play-based learning (Myers et al., 2022). Finally, a review of 40 out of over 1,000 personalized learning solutions in low- and middle-income countries categorized them by education purpose and setting. It found that almost two thirds were designed for supplemental learning only, offering multiple content, practice exercises, assessments and games, while three quarters could be used both in school and at home (UNICEF, 2022).

Some governments ambitiously aim for comprehensive integration of ICT in teaching and learning while others may prioritize, for example, personalization of learning, learning resource quality improvement and classroom infrastructure. In Estonia, the government began using ICT for school connectivity and teacher support reforms in the 1990s. Subsequently, curricula required the integration of digital technology in all subjects, signalling a move to digital culture integration in the Digital Turn Programme 2015–2018 and the Estonian Lifelong Learning Strategy 2020 (Pata et al., 2022).

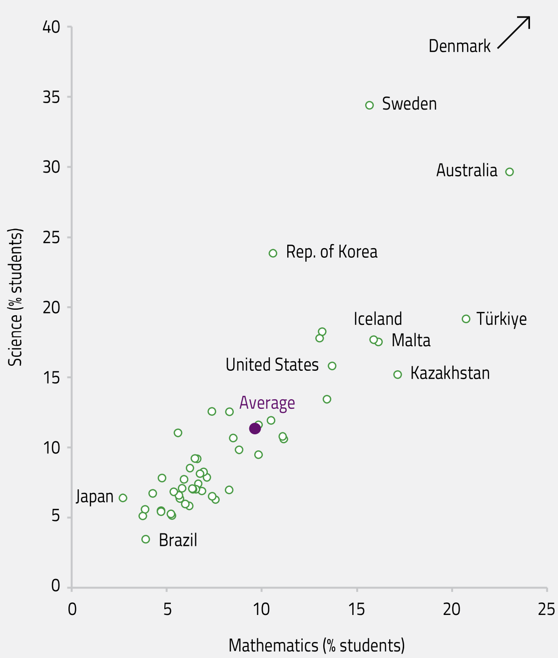
A 2018 review of education policy in the United States found that 39 out of 50 states had adopted policies to deliver personalized learning opportunities, allowing preschools and schools to define what personalization means and how to implement it. Responding to the Every Student Succeeds Act, which was signed in 2015, 17 states incorporated personalized learning into their policies, while 19 states aimed to ensure all students had a personalized learning plan aligned to their academic needs, interests and goals (Zhang et al., 2020).

In India, the National Education Policy 2020 highlighted the need for technological interventions to improve instruction, learning and teacher professional development (India Ministry of Education, 2020). Since the COVID-19 pandemic, in states such as Uttar Pradesh, there have been initiatives to use education technology products on a large scale to support improvements to foundational literacy and numeracy (Agrawal, 2023). Haryana became the first state to scale up personalized adaptive learning, selecting an education technology partner to provide relevant software and content on 500,000 tablets distributed to public school students (Press Trust of India, 2023).

FIGURE 4.1:

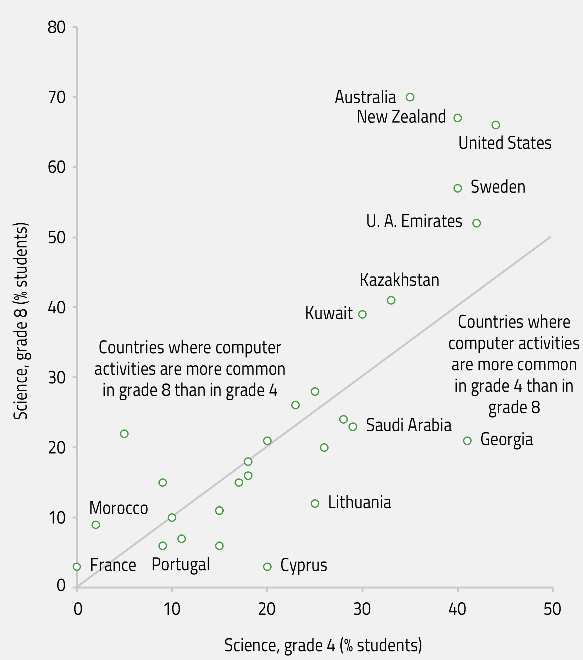
Even in upper-middle- and high-income countries, technology use in mathematics and science classrooms is not high

a. Percentage of 15-year-old students who used digital devices for at least one hour per week in mathematics or science classroom lessons, selected upper-middle and high-income countries, 2018



GEM StatLink: https://bit.ly/GEM2023_fig4_1a_
Source: 2018 PISA database.

b. Percentage of grade 4 and 8 students in classes whose science teachers reported doing computer activities at least once or twice a week, 2019

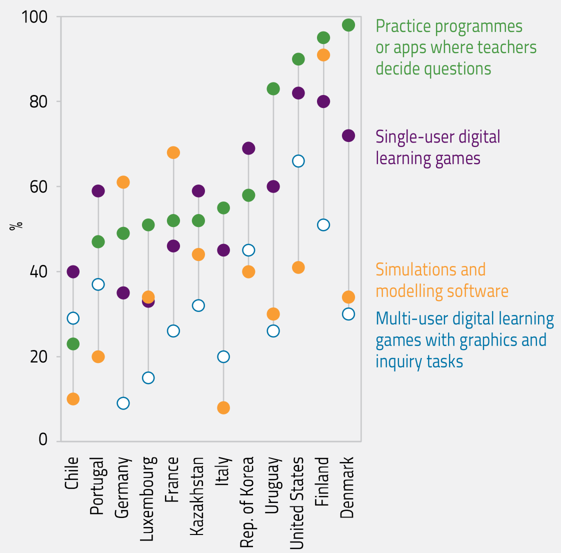


GEM StatLink: https://bit.ly/GEM2023_fig4_1b_
Source: 2019 TIMSS database.

FIGURE 4.2:

Software resources are fairly common in schools in high-income countries

Percentage of students at schools where ICT coordinators indicated that selected software-related resources were available for teaching and learning, 2018



GEM StatLink: https://bit.ly/GEM2023_fig4_2_
Source: 2018 ICILS.

Few countries are integrating AI in their education systems. Analysis of 24 national strategies launched between 2016 and 2020 found that while most discussed how to use education to develop expertise in this field, only one third highlighted integration of AI into teaching and learning. India and Kenya aspired to integrate AI to improve quality, while Malta and Spain viewed AI more as a complement to education to free up teacher time (Schiff, 2022). Another global survey found that only 11 of 51 countries had developed and implemented AI curricula (UNESCO, 2022).

> Few countries are integrating artificial intelligence in their education systems

Another major initiative is resourcing 'smart' classrooms, expanding digital infrastructure and enhancing interactivity through multimedia modes. China launched Smart Education Pilot Zones in 2019 to pursue various objectives for demonstration purposes, including using AI and big data to assess student learning and offering personalized services for teachers and students (IITE et al., 2022). In Guyana, the 2021 ICT in education policy and master plan aimed to provide computer labs and smart classrooms in primary and secondary schools. More resources are being allocated through the Support for Educational Recovery and Transformation Project for interactive screens and projectors in grades 2 to 6 (Guyana Ministry of Education, 2021:2022). In Rwanda, between 2016 and 2021, about half of the secondary schools were covered by the Smart Classroom initiative, equipping them with laptops connected to the internet as well as a projector (Resilient Digital Africa, 2021).

EVIDENCE ON TECHNOLOGY'S IMPACT ON LEARNING IS MIXED

Evidence on how technology interventions affect learning should inform the adoption and scaling up of technology use in education settings. Systematic, comprehensive reviews over the past two decades on the effects of the use of technology on learning generally find small to medium positive effects on learning outcomes compared to traditional instruction (Cheung and Slavin, 2013; Lewin et al., 2019; Topping et al., 2022). For instance, three recent meta-analyses, which reviewed a total of 272 studies at various education levels and in various countries, found an average positive impact of medium size (Chauhan, 2017; Hillmayr et al., 2020; Kärchner et al., 2022).

However, evaluations sometimes lack a control group. This makes it difficult to assess the impact of technology use compared to the same setting with a different medium of teaching or learning, and to attribute any positive effects to technology rather than other factors, such as added instruction, more resources or additional teacher support (Mayer et al., 2019). Moreover, research varies widely in terms of the duration of interventions, technology scope, education levels covered, contexts and samples. For instance, the duration of interventions affects the size of effects: some meta-analyses that investigated the effects of digital tools on learning have found that the longer the intervention, the smaller the impact (Hillmayr et al., 2020; Sung et al., 2016). As syntheses of existing evidence may obscure the mechanisms of impact, it is important to separately examine evaluations of individual types of technology-based learning interventions.

PRE-RECORDED OR BROADCAST LESSONS CAN SUPPORT DISADVANTAGED LEARNERS

Pre-recorded lessons are available in various formats – audio, television, tablets, desktop computers, laptops – to reduce gaps in access and learning **(Chapter 2)**. Transmitting live lectures directly to the classroom or using recordings can help teachers focus their time and efforts on integrating the lessons covered in the lectures rather than on preparing content. In India, technology-aided satellite teaching replaced one third of classroom teaching in more than 1,800 rural government secondary schools, resulting in improved mathematics and science scores (Naik et al., 2020). Introduced in 2004, the Modern Distance Education Program in Rural China policy is considered the largest education technology intervention ever implemented (**Box 4.1**). Analysis of a similar but smaller scale programme with computer-assisted teaching in China, conducted with 25 mathematics teachers and almost 2,000 students, found that it had improved lower secondary student performance. One third of the effect was attributed to improved instructional quality of local teachers who used lecture videos in lesson preparation (Li et al., 2023).

Various conditions need to be fulfilled for such interventions to succeed. It is not enough to just deliver materials without contextualizing them and providing support (**Box 4.2**). Teachers need to be integrated into these efforts. Randomized controlled trials of the e-Learn Project in Punjab province, Pakistan, evaluated two models of tablet integration. The first provided students with tablets preloaded with learning content and video explanations while the second provided teachers with the tablets to use for classroom teaching and to guide students. Compared to control groups, student achievement, as measured by mathematics and science test scores, decreased in the first model and improved in the second (Beg et al. 2019). ProFuturo, a large-scale technology-assisted learning programme implemented in Latin American, Asian and African countries, assists over 400,000 primary school teachers with tablets or computers preloaded with core educational content. An impact evaluation of the programme in Luanda, Angola, found that it had improved active teaching time and drill and practice exercises, which in turn improved student learning (Cardim et al., 2023).

Attributing effects to technology can be difficult for programmes with multiple components. For example, in Ghana, an intervention provided live, interactive satellite-transmitted lessons from Accra to 70 remote primary schools. The intervention included multiple components: a highly qualified teacher who provided the lecture over the broadcast, an additional teacher in the classroom, teacher training and sustained support, monetary incentives for teachers and for replacement teachers to tackle absenteeism, and shifting the curricular focus to basic building blocks to target teaching at the appropriate level. After two years, there was a gain in numeracy and literacy to which multiple factors beyond broadcasting contributed: local facilitators were more likely to be present, to teach in local languages and to target populations in need of remedial support (Johnston and Ksoll, 2022).

BOX 4.1:

Connecting urban with rural teachers helped improve student outcomes in China

A 2004 reform connected high-quality teachers in urban areas with more than 100 million students in rural primary and lower secondary schools in China. Over four years, the programme provided 264,000 satellite-receiving sets and 440,000 DVD player sets, while it built almost 41,000 computer rooms in rural schools. The interventions varied by school size: small primary schools received only DVD player sets, primary schools received DVD player sets and satellite sets, and lower secondary schools received all three interventions. Lectures and other study materials were then distributed to these rural schools.

The Ministry of Education selected the most accomplished teachers to record lectures and supporting materials such as interactive quizzes. Once these lectures were broadcast, local teachers helped solve technical issues and ensured that students focused on class-related activities. The objective was for the lectures to be integrated and not viewed as a separate teaching aid. Teachers delivered the lecture at a slow pace, repeating difficult content several times. The Ministry regularly reviewed and updated these lectures, using student and teacher feedback.

An impact evaluation between 7 and 10 years after the start of the intervention showed that it had increased Chinese and mathematics skills by 32% among lower secondary school students. In the longer term, students exposed to the intervention were more likely to be employed in occupations that focused on cognitive skills instead of manual skills. Exposure to the programme also led to an 18% reduction in the education attainment gap and a 38% reduction in the earning gap between urban and rural areas (Bianchi et al., 2022).

> It is not enough to just deliver materials without contextualizing them and providing support. Teachers need to be involved.

COMPUTER-ASSISTED SOFTWARE AND APPLICATIONS SUPPORT DRILL AND PRACTICE

Teachers in the United States have used drill and practice software extensively since the mid-1980s to help students master concepts. Meta-analyses showed that drill and practice applications that reinforced traditional instruction were more effective than tutorial applications that substituted for human instruction (Carnoy, 2004). Drill and practice applications include digital flashcard activities, in which students respond and receive feedback from the programme, and branching drills, where each question is determined by whether the previous one was answered correctly (Kuiper and de Pater-Sneep, 2014). An in-depth review of design elements of 23 mathematics applications used by children in the first three years of school in Brazil, Canada, China, Malawi, Sweden, the United Arab Emirates, the United Kingdom and the United States showed that targeted practice was the most common objective. Most applications targeted basic number skills while more advanced mathematics skills, such as fractions, were less frequently included (Outhwaite et al., 2022b).

Practice-based educational applications have been developed by the non-profit organization onebillion to improve foundational learning in seven countries. In Malawi, an e-learning platform for government primary schools was loaded with the applications, which included over 4,000 activity units targeting specific mathematics and reading skills, enabling self-paced learning, individualized reward, and feedback upon interaction with the software. Children learned through low-cost tablets. The software recorded application use in school and fed the information back to teachers. Early primary schooling outcomes were improved and the use of these applications has been scaled up through iterative evaluations (Pitchford et al., 2018; Pitchford, 2022).

Foreign language learning typically uses drill and practice software, but few of these applications have been rigorously evaluated. Applications such as Quizlet, launched in 2007, focus on developing ready-to-use sets of online flashcards for various languages (Sippel, 2022). Analysis of lower secondary schools in the Republic of Korea found that students who had used Quizlet scored better on vocabulary tests than students receiving traditional teacher-led instruction (Cho, 2021).

Evaluations in the use of Quizlet in university settings in Japan and Saudi Arabia showed significant improvement in vocabulary learning after 10 weeks and 1 month respectively (Dizon, 2016; Sanosi, 2018). But evaluations of Duolingo, a widely used foreign language application, which includes drill-focused instructional methods and game-based components, have generally been quantitative or based on purposive samples, with limited investigation on how the learning was facilitated (Shortt et al., 2021).

BOX 4.2:

Preloaded content needs to be adapted to context and come with tailored support

In the early 2000s, there was much optimism that the One Laptop Per Child project and other free device initiatives would help educate children in low- and middle-income countries (Warschauer and Ames, 2010). The model provided low-cost, low-maintenance laptops with low connectivity requirements and loaded with open-source learning materials which had been developed for free. The laptops aimed to promote learning by doing, encouraging students to share their experiences and learn together.

Several studies have documented the failure – in particular for girls – of the One Laptop Per Child and related models focused on hardware to improve learning outcomes (Evans and Yuan, 2021; Gupta and Sarin, 2022; Jordan and Myers, 2022). Reasons for failure include overambitious costing plans, unsustainability in local contexts and inadequate integration into pedagogical processes (Ames, 2019; Souter, 2021).

Peru had the largest One Laptop Per Child programme globally, with over 900,000 laptops distributed to rural, disadvantaged students (Trucano, 2012). An evaluation of data collected after 15 months of implementation in 318 rural primary schools showed that the programme had no positive impact on mathematics and language test scores, although there was some inconclusive evidence on positive effects on general cognitive skills. Implementation challenges and a lack of integration into existing pedagogical practices prevented learning gains. While the programme's aim was for laptops to be used at home and at school, only about 40% of students were taking the laptops home. While the laptops were preloaded with age-appropriate e-books, a lack of internet access and interfaces meant that it was difficult for children to install other games or applications (Cristia et al., 2017). Teachers were trained to use the laptops and the software but less so to implement the programme in classroom work. In practice, laptops were being used to copy texts from the blackboard. Students also learned how to do creative activities, but there was little pedagogical work (Cueto, 2023).

SUPPLEMENTING INSTRUCTIONAL TIME CAN DELIVER GOOD OUTCOMES WITH TEACHER SUPPORT

Several large-scale interventions have focused on computer-assisted interventions that involve games or practice sessions. In Morazan, El Salvador, after-school, offline delivery of the Khan Academy portal in grades 3 to 6 in 300 primary schools provided two additional lessons of 90 minutes per week of additional mathematics instruction, effectively doubling it. An evaluation found that teacher-assisted Khan Academy lessons outperformed the traditional approach to teaching mathematics (Büchel et al., 2020).

Comparing in-school and after-school versions of the same intervention shows that the latter tend to deliver better outcomes. In the Indian state of Gujarat, a computer-assisted learning model was provided to a relatively well-functioning network of schools run by a non-governmental organization. The programme was not used as a substitute for the teacher-delivered curriculum. Applying the model in school was found to reduce student learning, but when implemented as a complementary after-school programme, it generated large gains, especially for weaker and older students (Linden, 2008).

Three experiments in China provide evidence on the potential of technology when used as a supplementary intervention. First, an intervention which provided two 40-minute computer-assisted sessions per subject per week in 171 primary schools and required students to practice playing games was more effective when implemented outside school (Mo et al, 2015). Second, a computer-assisted learning programme in rural public schools was more effective when implemented by a non-governmental organization than a government agency because it was less likely to have been used to substitute for regular instruction and had more direct monitoring. Benefits likely came from the extra instructional time that was facilitated rather than the computer-assisted aspect of the programme (Mo et al., 2020). Third, another experiment with more than 4,000 students in rural China similarly showed that while a computer-assisted learning programme appeared to enhance academic outcomes, it was not the technology component that made the difference (Ma et al., 2020).

Advancements in educational platforms and tools powered by AI may allow time spent on repetitive tasks, such as preparing teaching resources and assessments, to be redirected towards facilitating classroom discussion (Bhutoria, 2022). But computer software can also disrupt teaching time and demands additional teacher inputs. A programme that provided supplemental mathematics software and instruction in 52 low-performing primary schools in the US state of California found that 2 years of its use produced no effect. Only 21% of teachers were observed drawing connections between the games and what the class was learning. The ability of such games to teach skills that transfer to the mathematics classroom may have been lower than expected and the programme required classroom teachers to reinforce and create linkages (Rutherford et al., 2014).

PERSONALIZATION AND SOFTWARE ADAPTATION CAN TARGET SUPPORT TO STUDENTS

There is a general trend towards enhancing personalization features that adapt or adjust to student learning levels. Personalized adaptive software generates analytics that can help teachers track student progress, identify error patterns, provide differentiated opportunities for practice, make feedback more specific and reduce teacher workload on routine tasks (Baker, 2016).

> Personalized adaptive software generates analytics that can help teachers carry out a variety of routine tasks

Rigorous evaluations of commercial software mostly come from the United States. They tend to have mixed results. The mathematics homework platform ASSISTments uses formative assessment to give students immediate feedback and guide teachers to use the data. An evaluation among grade 7 students in 43 schools in the US state of Maine showed that students used the programme for less than 10 minutes per day, 3 to 4 times per week and improved mathematics scores by 0.18 standard deviations (Roschelle et al., 2016), which is considered a low impact. Students with low prior mathematics achievement benefited the most: they may have benefited from teachers targeting their homework review around common errors or deeper discussions around solutions (Murphy et al., 2020).

The Carnegie Learning MATHia software provides students with one-to-one coaching in mathematics. A study in 147 schools across 7 states showed that its implementation improved the median upper secondary school student's performance by approximately eight percentile points (Pane et al., 2013). A 2021 study based on longitudinal data from 100,000 students in the US state of Florida found that using MATHia in lower secondary school led to better outcomes in algebra, especially for weaker students (Student Achievement Partners, 2021).

Not all widely used software interventions have strong evidence of positive effects compared to teacher-led instruction. ALEKS, an AI learning and assessment system, has been used by over 25 million students for mathematics, chemistry, statistics and accounting in the United States. A meta-analysis of 15 empirical studies between 2005 and 2015 found that it was as good as, but not better than, traditional classroom teaching (Fang et al., 2019). An updated analysis found that it was more effective when used to supplement traditional instruction (Sun et al., 2021).

A meta-analysis of 16 randomized controlled trials of digital personalized learning initiatives in low- and middle-income countries found a significant positive, if moderate, effect. Approaches which adapt to the learners' level had a significantly greater impact on learning than those that do not (Major et al., 2021).

Geekie, a Brazilian adaptive learning programme, uses machine learning to provide personalized learning. It flags specific learning difficulties encountered by students, helping teachers intervene as necessary. An analysis conducted with 400 schools, 14,000 teachers and 130,000 families found that Geekie was highly rated, but evaluations of such commercial products typically do not include impact assessments (Myers et al., 2022). Personalized adaptive learning is also spreading in India. Evaluations of one software tool documented learning gains for weak students (**Box 4.3**).

Artificial intelligence may be built into personalized adaptive technology software to help select the most appropriate content. For instance, writing tools can scaffold student writing by automating proofreading, translating and providing feedback (Yan, 2023). Secondary school students using Google Translate in Chile as part of an English as a foreign language course significantly improved their writing style and accuracy relative to those who did not use the tool (Cancino and Panes, 2021). Teachers evaluated positively writing assignments completed with Google Translate in a Hong Kong, China primary school on grammar, vocabulary and comprehensibility (Stapleton and Kin, 2019). But such positive evaluations analyse the finished products, not how students engaged and learned with these tools (Stevenson and Phakiti, 2019). Students might focus on correcting their errors and not on constructively applying the feedback to improve their writing (Koltovskaia, 2020). Similarly, overdependence on chatbots like ChatGPT may reduce students' higher order cognitive skills, such as creativity, critical thinking, reasoning and problem-solving.

BOX 4.3:

A commercial personalized adaptive software in India has invested in its evaluation

Mindspark, developed by Educational Initiatives, is a fee-charging software service focused on personalized learning for English, mathematics and science. The software includes an extensive item-level database of test questions and student responses to benchmark students' initial learning level and help personalize the material. Partnerships have been reached with state governments, for instance, of Rajasthan (Bhargava, 2022). During the COVID-19 pandemic, the software was made available online in 10 states across India for learners to use at home (Ei Shiksha, 2021).

The effectiveness of the software was evaluated in after-school centres and public and private schools in India. In after-school centres serving low-income neighbourhoods in Delhi, Ei Mindspark was used for 6 days of instruction per week for 90 minutes per day: 45 minutes of self-driven learning and 45 minutes of instructional support from a teaching assistant. Attending the centres for 90 days resulted in significant gains in mathematics and language, with relatively higher gains for students who performed worse at the baseline. The effect is linked to combining the computer-aided learning programme, group-based instruction and extra instructional time. The evaluation argued that the positive effect could be attributed to the programme's adaptiveness and its ability to target instructional materials at the level of the student, since a comparable after-school tutoring programme in operation at the same time had no impact on test scores (Muralidharan et al., 2019).

In less disadvantaged schools, studies showed that the software helped with remediation in mathematics. One study focused on independent practice among students in grades 4 to 7 in unaided private schools in 7 cities. After six months, additional time on practice had no effect on the average student's achievement, but students who initially had low performance slightly outperformed similar students who did not use the software (de Barros et al., 2022). Another impact analysis focused on students in grades 6 to 8 in 15 model public schools. After nine months, personalized learning had no effect on the achievement of the average student but students with low initial performance outperformed their counterparts by 0.22 standard deviations, a small effect, helping them catch up with their peers (de Barros and Ganimian, 2021).

By simplifying the process of obtaining information, it can negatively impact student motivation to perform independent research and derive solutions (Kasneci et al., 2023).

DIGITAL TECHNOLOGIES APPEAR TO IMPROVE STUDENT ENGAGEMENT

Digital technologies – games, interactive whiteboards, simulators and collaboration tools – when effectively integrated in pedagogy by teachers and with appropriately designed features can engage students through varied representations and interaction. Some of these tools can also enhance parental and caregiver support and indirectly affect student outcomes.

DIGITAL GAMES FACILITATE KNOWLEDGE ACQUISITION IN INTERACTIVE WAYS

Educational games and the incorporation of gamification elements in digital learning can improve academic and non-academic skills through increasing learners' interaction (Schindler et al., 2017). Playing computer games has been found to support learning in science, mathematics and second languages compared to other forms of instruction. They can motivate students to initiate game play and persist in learning for longer durations (Mayer et al., 2019). A systematic review of 43 studies on digital game–based applications in mathematics education found a mostly positive impact on knowledge acquisition, cognitive skills and motivation to study mathematics (Hussein et al., 2022). In Brazil, a game-based intervention to help primary school students learn and practise four basic arithmetic operations using tablets involved playing the game for up to 20 minutes during the school day for two months. Compared to a control group, students' scores in mathematics increased, an impact that persisted a year after the evaluation (Hirata, 2022).

Game-based applications are being used more and more in low-resource settings to practise literacy and mathematics skills. In Cambodia, the Total Reading Approach for Children Plus initiative is a game-based application developed by a non-governmental organisation. It promoted early grade reading among struggling grade 1 to 3 students with a pedagogy that focused on practising the Khmer alphabet, vocabulary and phonetics, complementing the early grade reading curriculum. A study found positive perceptions of its impact on grade 2 and 3 students in reading. The interactive game-based nature, user-friendly interface and related instructional support engaged learners and educators, although the design needed further alignment to users' needs and capabilities (Oakley et al., 2022).

A systematic review of literature on mobile-learning applications targeting refugees showed that one in three applications studied were learning approaches based on games (Drolia et al., 2022). In Jordan, using Feed the Monster, a game-based smartphone application, for 22 hours over 2 months improved foundational literacy skills among Syrian refugee children. The game also increased peer interaction and received positive feedback from parents (Koval-Saifi and Plass, 2018).

A review of empirical and theoretical studies on gamification showed that gaming strategies and features, such as multimedia, graphics, role playing, competition through leader boards and rewards with digital points and badges for completing activities, had a positive influence on students' motivation to learn, decision-making and collaboration skills (Dichev and Dicheva, 2017). Kahoot!, a game-based learning platform, was reportedly used by at least half of all students in the United States in 2022, as well as more than 24 million users and 8 million teachers globally (Kahoot!, 2023). A review of 93 studies found that Kahoot! can have a positive effect on learning compared to other tools and approaches, in various contexts and domains. Qualitative studies identified the use of leader boards, audiovisual features like high-quality animated graphics, individual feedback and increased classroom interaction as contributing to an engaging learning environment (Wang and Tahir, 2020).

Adult interaction can influence the learning impact of game-based interventions. GraphoGame is an adaptive digital game used in over 20 countries that promotes reading fluency by helping children develop sound–symbol connections. It automatizes repeated practice of word recognition and provides immediate feedback. A meta-analysis of 19 studies measuring its impact on word reading in multiple languages did not find an overall positive impact. However, while self-use was associated with no effect, adult involvement was associated with positive effects (McTigue et al., 2020). A French study of GraphoGame with a sample of grade 1 students from disadvantaged neighbourhoods found that 4 months of playing the game 4 times a week for 30 minutes had a positive impact on word-reading fluency, as teachers provided active support throughout (Lassault et al., 2022).

Augmented and virtual reality technology in games can also affect student attitudes towards certain subjects. A systematic review found that digital simulation–based games had a positive impact on learner motivation to study physics (Ullah et al., 2022). Simulations of real-world scenarios in digital games allow students to role-play, practise prosocial behaviours and learn decision-making in less intimidating virtual spaces (Rui, 2023). A game-based social and emotional learning programme for grade 3 students in the US state of California, including weekly videos with stories and narratives, a game and an assessment, improved interpersonal communications and skills, including emotional regulation and empathy, compared to a control group (Sanchez et al., 2017).

> Simulations of real-world scenarios in digital games allow students to role-play, practise prosocial behaviours and learn decision-making

INTERACTIVE WHITEBOARDS CAN ENGAGE LEARNERS TO SUPPORT LEARNING

Interactive whiteboards or smartboards can potentially support the visual, auditory and tactile experiences of teaching and learning (Abdullah et al., 2021). In European Union countries, the number of primary school students per interactive whiteboard halved from 111 in 2011/12 to 56 in 2017/18 (Deloitte and Ipsos MORI, 2019). A meta-analysis found smartboards to be more effective than traditional instruction based on lectures, due to their potential to engage learners. However, the effects may be linked less to their interactivity and more to the pedagogical approaches of the teachers using them, such as collaborative and active learning (Shi et al., 2020). Pedagogical integration of whiteboards by teachers determines whether they are used merely as projection tools or for effectively stimulating student interaction and classroom activities (De Vita et al., 2018).

Governments have significantly invested in interactive whiteboards with varied impacts. The United Kingdom was an early large-scale adopter in the 2000s. An evaluation of their pilot introduction in 200 classrooms found that teachers and 9- to 11-year-old students were overwhelmingly supportive (Moss and Jewitt, 2010). As a result, the programme was scaled up and, by 2007, they were being used extensively in teaching (Smith et al., 2008). However, interactive whiteboards were often used simply as a replacement for blackboards and their interactive capabilities not necessarily used (DiGregorio and Sobel-Lojeski, 2010). In Türkiye, the Ministry of National Education introduced smartboards in more than 570,000 classrooms as part of a nationwide ICT reform project, starting in 2011, to integrate ICT into the education system (Esara and Sinan, 2017). A meta-analysis of 47 experimental studies on the use of smartboards in Turkish classrooms for multiple subjects found large positive effects on achievement (Akar, 2020).

When used as a teaching aid, smartboards can help explain complex concepts and save classroom time. As part of an effort to digitize primary schools in Senegal, an ICT intervention, Project Sankoré, introduced interactive whiteboards in classrooms along with pre-installed content software. An evaluation of 122 schools reported that the boards' visualization capabilities allowed teachers to not have to draw complex diagrams and use the saved time for class discussions. Student test scores improved in French, mathematics and life sciences (Lehrer et al., 2019).

The quality of teacher training is critical. In Catalonia, an autonomous community of Spain, a programme provided interactive whiteboards along with one-to-one devices to more than 600 schools. Teachers reported using interactive whiteboards mostly like a common projector to display digital textbooks and slides. But teachers who had received specialized training using examples from publishers and peers were more likely to use the boards interactively to generate content or allow students to write on them (Grimalt-Álvaro et al., 2019).

SIMULATION SUPPORTS EXPERIENTIAL TRAINING IN SCIENTIFIC AND TECHNOLOGICAL FIELDS

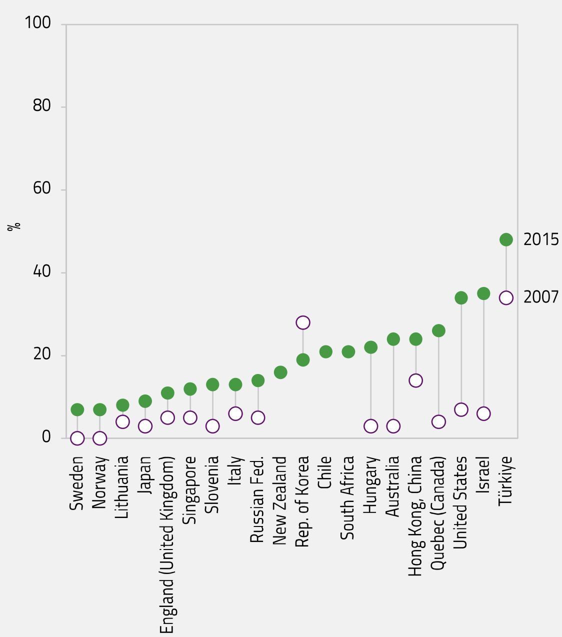
Augmented, mixed or virtual reality are being used as experiential learning tools, providing attractive visualizations, interactivity and opportunities for repeated practice in life-like conditions. Such simulations facilitate practical learning in fields such as medicine and engineering (Angel-Urdinola et al., 2021) but are also being used in secondary school science classrooms. According to teacher reported data in the TIMSS, the share of grade 8 students who experienced simulations in science classrooms increased by 12 percentage points between 2007 and 2015 but by twice as much in Israel and the United States. The highest share was observed in Türkiye, with half of students experiencing simulations (Vincent-Lancrin et al., 2019) (**Figure 4.3**).

Online science laboratories allow unlimited repetitions of experiments in a safe and cost-efficient manner; they can be software-based, virtual or remotely controlled physical laboratories (Potkonjak et al., 2016). The Global Online Science Labs for Inquiry Learning in Schools, or Go-Lab, initiative funded by the European Union provides access to 600 virtual laboratories to students and teachers of science, technology, engineering and mathematics in 50 countries in Europe and Africa, often in partnership with ministries of education (Go-Lab, 2023). The labs enable experiential, collaborative and inquiry-based learning by allowing teachers to demonstrate and students to conduct repeated and diverse scientific experiments. In Estonia, the University of Tartu Institute of Education has incorporated Go-Lab into teacher education programmes to foster a teaching culture that emphasizes inquiry and collaboration. The Ministry of Education has revised its digital science assessments, emphasizing scientific inquiry abilities drawing from Go-Lab's inquiry-based learning model (Gillet et al., 2017).

FIGURE 4.3:

More and more students are studying science with computer simulations

Percentage of grade 8 science students studying natural phenomena using computer simulations, selected countries, 2007 and 2015



GEM StatLink: https://bit.ly/GEM2023_fig4_3_
Source: Adapted from Vincent-Lancrin et al, 2019)

> Training based on virtual reality may be less effective than real-life training but more effective than other digital methods such as video demonstrations

Practical training based on virtual reality may be less effective than real-life training but more effective than other digital methods such as video demonstrations. A meta-analysis of 145 empirical studies of technology effectiveness in simulation-based learning environments in tertiary education found that live simulations involving human patients in medical education had the highest positive impact on learning outcomes compared to all other digital simulations. However, compared to viewing two-dimensional computer screen simulations, virtual reality simulations were associated with larger positive effects, allowing for interaction and stimulating student sensory perceptions (Chernikova et al., 2020).

Simulated environments or digital three-dimensional models of workplaces support experiential learning that engages students, encourages inquiry and allows for repeated practice opportunities with reduced occupational risks and hazards (ILO, 2021). They can be an alternative for or supplement on-the-job training (OECD, 2021). Accordingly, augmented and virtual reality technology is being used in technical and vocational education and training (TVET) institutions. Denmark has established a Knowledge Centre to foster the use of advanced simulation technologies in TVET. In a survey of its social and healthcare programme students, almost 70% declared that virtual reality was an effective supplement to regular teaching and more than 40% reported improvements in learning outcomes (OECD, 2021).

MilleaLab, a software platform used to create virtual reality–based educational content, was developed in 2019 by a partnership between the Southeast Asian Ministers of Education Organisation Regional Open Learning Centre and the Indonesian TVET provider Shinta VR. Millealab has enabled access to virtual learning courses to 1,500 schools and has trained 5,200 teachers in the development and use of virtual reality–based learning content, even without them having coding skills knowledge (UNESCO-UNEVOC, 2021a).

Virtual reality training modules provide an interactive environment for students to train in preparation for the workplace (European Union, 2020) and some professions with high-risk work environments have adopted simulation technology in their training and assessment programmes (Morélot et al., 2021). In the Flemish Community of Belgium, teachers are developing high-quality virtual reality training modules as part of VRGhoote, a secondary TVET training initiative which allows students to safely train in a simulated high-risk work environment and practise operating machinery such as wind turbines (European Commission, 2020). In Ecuador, the Secretariat of Higher Education, Science, Technology and Innovation has implemented

BOX 4.4:

Flipped classrooms are changing instruction in higher education

Flipped classrooms, a type of blended pedagogical approach, are being employed in higher education, aided by the development of diverse technological tools for recording, editing and publishing videos, and online video platforms (Bredow et al., 2021; Robertson and Flowers, 2020). Students study the material before class, by watching online lectures or pre-recorded videos, at their own pace and apply the learning material during class, allowing the classroom experience to shift from being teacher-centred to learner-centred (Strelan et al., 2020).

This approach has been mainly evaluated in higher education settings (Jdaitawi, 2019) and notably in the United States and in Asian countries including China, Malaysia and the Republic of Korea (Kushairi and Ahmi, 2021). Given evidence that it improves student engagement (Lee, 2018), the Republic of Korea Ministry of Education has encouraged the use of flipped classrooms in higher education, especially for teaching science. Universities may make it mandatory for newly hired faculty to teach flipped classes across disciplines (Kim, 2021).

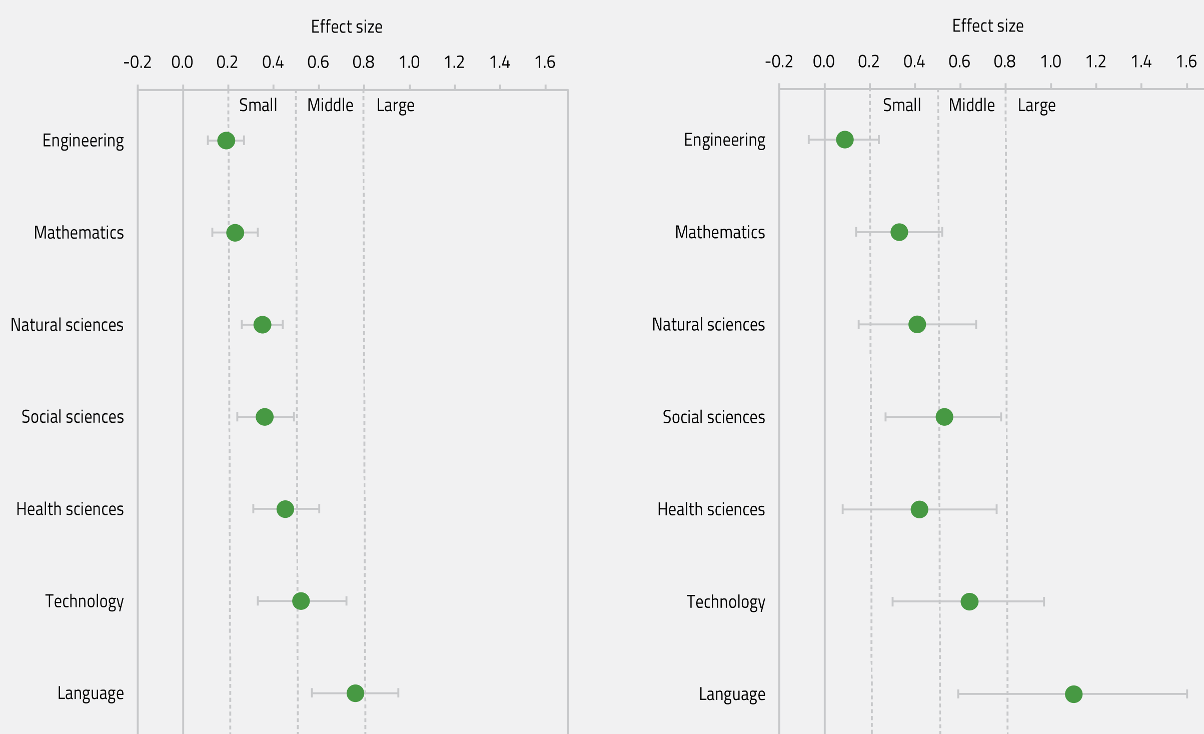
A meta-analysis of 95 studies showed that the flipped classroom model had a moderate positive effect on learning achievement and motivation compared to the traditional classroom model. In class, tools such as online discussion forums and games produced larger effect sizes than online learning platforms. Of the resources used before class, video recordings had the highest effect (Zheng et al., 2020). Effectiveness also varies by the subject taught. A review of more than 300 studies highlighted the positive effect on both academic and intra-/interpersonal outcomes of flipped classroom interventions using video support but the effect size was larger for language and technology than for engineering and mathematics (Bredow et al., 2021) (**Figure 4.4**).

FIGURE 4.4:

Flipped classrooms improve learning in a range of subjects

Average effect size of flipped classroom interventions in higher education, by subject matter, multiple studies, 2010s

a. Academic outcomes *b. Intra-/Interpersonal outcomes*



GEM StatLink: https://bit.ly/GEM2023_fig4_4_

Note: Green dots show the average effect and the lines show the average variability of the estimates.

Source: Adapted from Bredow et al., (2021).

However, effective use of this pedagogical approach is contingent on students being able to self-regulate their learning and having ICT equipment at home (Lo and Hew, 2017). Teachers also need to be able to use classroom time to effectively stimulate student collaboration and need to prepare lessons before class. Adapting to two modes of instruction can increase their workload (Bülow, 2022).

ActiVaR, a national programme which integrates virtual reality technology to recreate hazardous situations, where students can gain practical experience in identifying and mitigating industrial risks. The added gamified experience allows students to practise and teachers to provide feedback in real time (Angel-Urdinola et al., 2022).

The COVID-19 crisis boosted TVET providers' use of simulation technologies as an alternative to practical on-the-job training. In Malaysia, the Tun Hussein Onn University developed the Digital TVET Learning Platform. Teachers integrated augmented and virtual reality components in their lessons to simulate real-life problems in classroom and laboratory activities (UNESCO-UNEVOC, 2021b). Yet according to a joint survey of TVET providers, policymakers and other stakeholders in 126 countries, less than 20% of upper-middle- and high-income country respondents reported using simulations, augmented and virtual reality tools (ILO et al., 2020).

COLLABORATIVE TECHNOLOGIES FOSTER COMMUNICATION AND CLASSROOM ENGAGEMENT

Digital technology can help students collaborate across boundaries, provide a visual representation of ongoing assignments, facilitate asynchronous group work and promote knowledge co-creation (Wang and Shen, 2023). In a meta-analysis of 425 empirical studies, almost all studies that explored the role of computers in fostering collaborative learning reported significant positive effects on student perceptions, group task performance and social interaction (Chen et al., 2018).

Online discussion forums and cloud-based word-processing platforms allow learners to collaborate on the same task at the same time (Wang and Shen, 2023). A review of 34 empirical studies on technology-supported collaborative writing found that wikis, Google Docs, offline word processors, Facebook, chats and forums had a positive impact on student engagement, group interaction and peer feedback (Zhang and Zou, 2021). In Bangladesh, students who used wikis for online collaborative writing had a positive perception of online word processing, such as being able to write and edit recursively (Ara, 2023). A quasi-experimental study in the Islamic Republic of Iran compared two classes of English learning and found that the use of Google Docs for peer editing improved learners' writing skills compared to traditional face-to-face settings (Ebadi and Rahimi, 2017).

Audio and video conferencing tools for synchronous and asynchronous distance learning can facilitate collaborative learning by reducing time and space barriers (Wang and Shen, 2023). Virtual learning environments encourage participation from more vulnerable and passive students by allowing them more time to think and reflect on their interventions that can be sent in writing compared to speaking up in traditional classroom settings (Chen et al., 2018). One such approach, the flipped classroom, combines face-to-face with online learning (**Box 4.4**).

However, collaborative learning pedagogies need to be integrated into the teaching process. A quantitative meta-analysis of 46 studies on augmented reality interventions indicated that the highest impact on learning outcomes was obtained when interventions employed a collaborative pedagogical approach (Garzón et al., 2020). Studies on online peer editing have emphasized that the quality of student interaction depends on the pedagogical approach employed by the teacher (Zhang et al., 2022). In Sweden, Write to Learn, a structured pedagogical approach to using ICT in early grades, emphasizes collaborative work and classroom interaction. For writing tasks, students use software to share their texts with peers and teachers continuously give and receive feedback during the process. An analysis of grade 1 and 3 students showed that 78% of students taught with this approach passed the national standard tests in literacy and mathematics, compared to 59% of those who followed the traditional method and 50% of those who used ICT without collaborative feedback (Genlott and Grönlund, 2016).

> "Short, light-touch, nudging interventions involve sending parents regular reminders to engage with their children's learning"

TECHNOLOGY HELPS PARENTS ENGAGE WITH THEIR CHILDREN'S LEARNING

Technology provides teachers with several low-cost and convenient ways to communicate up-to-date information to parents about their child's school progress (Nicolai et al., 2023). ICT can be used to improve parental knowledge and practices through training, informing and nudging them (Nicolai et al., 2023). Short, light-touch, nudging interventions involve sending parents regular reminders to engage with their children's learning using low-cost modalities, such as through text messages.

A systematic review of 29 studies found that such behavioural interventions resulted in improvements in academic outcomes (See et al., 2020), school attendance, and parental involvement in activities at home and in school (Berlinski et al., 2021). In Côte d'Ivoire, nudges were sent twice a week for a full year to caregivers in 100 public schools and were found, compared to a control group, to be associated with halving student dropout (Lichand and Wolf, 2020). In low-income neighbourhoods of Cape Town, South Africa, more than 1,000 households were sent weekly text messages to encourage children to regularly attend a government after-school programme. After 10 weeks, learners whose parents received text messages attended the sessions 6% more on average than learners who belonged to a control group (Owsley, 2017).

The Parent Engagement Project sent an average of 30 texts to each parent over an 11-month period in 36 English secondary schools. The texts included information on child performance and upcoming tests and assignments. An independent evaluation found that children whose parents received these texts improved their learning in mathematics by the equivalent of a month's worth of additional progress and reduced school absenteeism compared to children in the control group. Most parents accepted the content, frequency and timing of messages (Education Endowment Foundation, 2016).

READY4K!, a preschool literacy programme implemented in San Francisco, United States, sent parents three text messages per week over a duration of eight months on easy-to-implement home literacy activities. Children whose parents received these text messages performed higher in literacy tests, especially those who previously scored below the class median (York and Loeb, 2018). A smartphone application, EasyPeasy, sends parents of preschool-age children weekly text messages with educational game ideas to implement at home. An evaluation of its implementation over 20 weeks in about 100 nurseries in the United Kingdom reported improvements in home learning activities (Robinson-Smith et al., 2019).

Moreover, learning with technology at home makes parental help particularly important so that students can apply the feedback received, as it became clear during COVID-19 (**Box 4.5**). Children sometimes struggle to use feedback received from education technology software without adult support (Vasalou et al., 2021).

BOX 4.5:

COVID-19 distance learning relied on engaging parents

During the COVID-19 school closures, governments used ICT to communicate with parents and caregivers to engage them to help their children's learning. Information campaigns using text messages and instant messaging platforms provided regular updates and shared resources for supporting home learning. After the closure for early childhood development centres, the Colombian Institute of Family Welfare launched a distance education initiative that targeted 1.7 million disadvantaged children. The programme relied on WhatsApp and other social media platforms to relay guidance to caregivers on simple pedagogical activities for children's development at home (Vincent-Lancrin et al., 2022). The Madhya Pradesh state department of education in India, under the #Ab padhai nahi rukegi (#Learning will not stop) campaign, created a WhatsApp group for each of its over 50,000 schools to share learning materials, which reached over 1.9 million parents and 200,000 teachers. A dedicated WhatsApp monitoring team was set up to oversee the content that was being circulated (Batra et al., 2022).

Schools and teachers engaged with parents using phone calls and instant messaging platforms to support them, deliver lessons and receive children's homework (Nicolai et al., 2023). In Botswana, the Ministry of Basic Education leveraged weekly text messages and phone calls from teachers to parents to continue implementing the Teaching at the Right Level programme to improve foundational literacy and numeracy. During the pandemic, parents received over-the-phone tutoring on basic numeracy concepts. An evaluation among 4,500 households found primary school children's foundational numeracy skills improving compared to a control group. Parents engaged more with their children in education activities and could correctly identify their child's learning level and needs (Angrist et al., 2022). In Mexico, teachers used WhatsApp to communicate with students and parents via text, collect pictures of student work, and answer student questions through voice or video calls (Castellanos-Reyes et al., 2022).

Despite their potential, the uptake and effectiveness of these interventions are limited by factors such as parental education levels, caregiver beliefs about education, and lack of time and material resources (Nicolai et al., 2023). A 24-week behavioural nudge via text messages to increase caregiver engagement in Ghana found that it increased at-home and in-school engagement of those who had attended school compared to their peers with no education (Aurino et al., 2022).

INTENSIVE TECHNOLOGY USE NEGATIVELY IMPACTS STUDENT PERFORMANCE AND INCREASES DISRUPTION

In contrast to digital technology's potential to improve education, there are also risks of ICT in education, which are often ignored by research and evaluations. Student use of devices beyond a moderate threshold may have a negative impact on academic performance. The use of smartphones and computers disrupts classroom and home learning activity. A meta-analysis of research on the relationship between student mobile phone use and educational outcomes covering students from pre-primary to higher education in 14 countries found a small negative effect, which was larger at the university level. The decline is mostly linked to increased distraction and time spent on non-academic activities during learning hours. Incoming notifications or the mere proximity of a mobile device can be a distraction, resulting in students losing their attention from the task at hand. The use of smartphones in classrooms leads to students engaging in non-school-related activities, which affects recall and comprehension (Kates et al., 2018). A study found that it can take students up to 20 minutes to refocus on what they were learning after engaging in a non-academic activity (Carrier et al., 2015; Dontre, 2021). Negative effects are also reported in students from the use of personal computers for non-academic activities during class, such as internet browsing, and in their peers who are in view of the screen (Hall et al., 2020).

Studies using data from large-scale international assessments, such as PISA, also indicate a negative association between excessive ICT use and student performance (Gorjón and Osés, 2022). By categorizing ICT usage at home and in school as low, medium or high, more intensive use beyond a threshold was most often found to be correlated with diminishing academic performance while moderate usage was most often associated with positive academic outcomes. Analysis of 2018 PISA data from 79 countries constructed an online activity index based on online activities such as emailing, scheduling events, web browsing and chatting. After controlling for various student-, school- and country-level factors, a positive association was found between ICT use and reading, mathematics and science scores up to a threshold of optimal use. Beyond a 'several times a week' threshold, diminishing academic gains were reported. The finding that excessive use of ICT does not provide extra returns beyond a level remained consistent across all socioeconomic categories of students (Bhutoria and Aljabri, 2022).

> Incoming notifications or the mere proximity of a mobile device can be a distraction, leading to students losing their attention from the task at hand

Medium levels of ICT use were consistently associated with better reading outcomes in another study that used PISA data. While the number of students classified as high ICT users rose between 2009 and 2018, significant positive impacts on academic outcomes were not observed (Borgonovi and Pokropek, 2021). After controlling for gender and socioeconomic status, analysis of 2015 PISA data from the Netherlands found that students with moderate access and use of ICT for homework, both at and outside school, had the highest reading performance (Gubbels et al., 2020).

Studies on teacher perceptions of the use of tablets and phones highlight difficulties in classroom management, when students visit websites other than those indicated by teachers or due to the increased level of noise in the classroom (Nikolopoulou, 2020). More than one in three teachers from seven countries that participated in the 2018 ICILS – and one in two teachers in Denmark – agreed that the use of ICT in classrooms distracts students from learning (Fraillon et al., 2020). The use of social media in the classroom is also disruptive, increasing academic distraction with negative effects on learning outcomes (Dontre, 2021). Analysis of PISA data between 2009 and 2018 showed a negative corelation between the use of social media in school and digital reading performance (Hu and Yu, 2021).

Online learning, such as during the COVID-19 pandemic, relies on student ability to self-regulate learning and may therefore put low-performing students further at risk of disengagement; experimental studies indicate that high-performing students find it easier to engage with technology in productive ways (Bergdahl et al., 2020). In Belgium, the Netherlands and Switzerland, not only did student performance decline, but inequality increased, likely due to factors such as a lack of family support. In the Netherlands, after eight weeks of school closure, learning losses were up to 60% greater among students whose parents were less educated (Azevedo et al., 2022). Analysis of more than 2.1 million primary and lower secondary school students in 10,000 schools in the United States found that schools in high-poverty neighbourhoods spent about 5.5 more weeks in remote instruction in 2020/21 compared to schools in low- and medium-poverty neighbourhoods and reported lower academic outcomes (Goldhaber et al., 2022).

The switch to online learning affected primary school learners more than older students, who may have been able to sustain their learning better in a remote environment. In Switzerland, in a comparison eight weeks before and during school closures, secondary school students sustained learning progress in online learning, while learning gains for primary school children slowed down. Both primary and secondary school children learned twice as fast from in-person instruction compared to remote instruction (Tomasik et al., 2021).

Apart from immediate disruptions to teaching and learning, the use of technology is associated with negative impacts on physical and mental well-being and increased susceptibility to online risks and harms, which affect academic performance in the long term. Education systems have adopted various approaches, ranging from restricting use of devices to banning them completely **(Chapter 8)**.

> Positive impact is often dependent on strong pedagogical alignment and teacher input

CONCLUSION

Technology has great promise for improving existing teaching and learning processes. However, evidence of success is limited and this is particularly true of large-scale research that systematically explores how technology can facilitate positive changes in a sustained way and in diverse contexts. Attributing conclusive, specific learning outcomes to hardware or software is challenging. Positive impact is often dependent on strong pedagogical alignment and teacher input.

Evidence on the use and effectiveness of technology shows that beyond affecting individual learning outcomes, it can both facilitate and disrupt teaching and learning processes. While technology offers many affordances – supplementing and personalizing instruction, offering more opportunities for practice, stimulating student engagement through audiovisual, interactive and collaborative ways – it can also increase the risk of distraction and disengagement.

Given the overwhelming number of technology products and platforms available, governments need to base their decisions on procurement and scaling up on reliable evidence that looks at the long-term effects of interventions, carefully considering all pedagogical elements involved. The design and delivery of education technology interventions need to be tailored to local contexts. Successful technology interventions rely upon the long-established building blocks of strong pedagogical integration by teachers, additional instructional time and robust facilitation.