

Catalysing Education 4.0

Investing in the Future of Learning for a Human-Centric Recovery

INSIGHT REPORT

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Executive summary

Even before the COVID-19 pandemic, millions of children and young people were out of school globally – and, among those in school, many were not learning the skills needed to succeed economically in the age of the Fourth Industrial Revolution (4IR).¹ The pandemic has further exacerbated these trends, with nearly 1.6 billion children and young people impacted by school closures over the past two years, and minimal access to remedies such as remote learning among those already most marginalized.

The compound effects of COVID-19, pre-existing education inequalities and the rapid technological change of the 4IR underline that simply returning to the pre-pandemic status quo risks undermining not just the opportunities and well-being of today's generation of young learners, but the very foundations of global economic recovery and future prosperity. For any post-pandemic recovery plan to be successful and sustainable in the long term, a comprehensive approach to investment in high-quality, innovative, future-proof education systems must be a strategic priority.

There is a unique window to identify opportunities for fundamental, strategic investments in transforming primary and secondary education as part of the broader post-pandemic recovery, and reimagine an education system that is inclusive, focuses on the breadth of skills needed to be successful in the age of the 4IR, and leverages technological and pedagogical innovation to put learners at the centre of learning.

Previous work by the World Economic Forum has summarized such a vision to prepare students for the economies of tomorrow as 'Education 4.0'. This insight report highlights that:

- Global inequalities persist in years of schooling attainment, as well as schooling quality. In addition, school closures due to the COVID-19 pandemic have led to a schooling loss of over one-half year, on average, which is projected to lead to a 3.9% decline in lifetime incomes and a loss of up to \$17 trillion globally.
- A single \$1 investment in a child's education yields as much as \$5 in returns over a lifetime. An additional year of education on average translates to 9% higher lifetime earnings,² and in some cases up to 15% higher.³ The returns in lower-income countries are even higher than those in higher-income countries.
- We estimate that a global improvement in students' collaborative problem-solving capacity to the average level of today's top 10 scoring countries could add an additional \$2.54 trillion in increased productivity to the global economy.
- In absolute terms, Europe and South Asia – with estimated increases in productivity of \$0.51 trillion and \$0.46 trillion, respectively – stand to benefit the most. However, relative to today's size of their regional economies, Sub-Saharan Africa and Latin America and the Caribbean also stand to benefit significantly.
- The education sector also provides opportunities for job creation. While 85 million teachers are currently employed worldwide, an additional 69 million teachers will need to be recruited in the coming years to reach U.N. Sustainable Development Goal (SDG) 4: Quality Education. Each of these roles must be supplemented with additional roles in education leadership, specialist and complementary

education support roles, providing additional opportunities for job creation in the sector.

- In addition, there are myriad of other societal benefits, such as greater civic engagement and stronger institutional trust, leading to greater well-being for nations and their citizens across the globe.
- Key investment areas include new assessment mechanisms, adoption of new learning technologies and empowerment of the teaching workforce through skill upgrading and innovative pedagogy development.
- Currently, educational investment – in developing economies in particular – is attracting relatively little capital from the private sector, blended finance or even multilateral development finance institutions. At \$5 trillion, the global education sector accounts for about 6% of global GDP, yet it has attracted only about \$300 billion in investments in 2020. This is less than one-tenth of the investment in the comparably-sized global healthcare sector.

- The total cumulative volume of public-private blended/impact investments related to UN SDG 4 over the past decade stood at a modest \$1.5 billion in 2021, compared to nearly \$16 billion in global healthcare.

- The largest and fastest-growing investments around education have been in education technology, or 'edtech', which are projected to attract about \$404 billion of capital globally by 2025, amid increased recognition of the importance of technology-enabled and remote learning during the pandemic.

To realize this vision, stakeholders from all parts of society have a role to play – from governments and non-governmental agencies, to businesses, investors and educators, to parents and caregivers as well as learners themselves. In putting front and centre the economic case for upgrading our existing education systems, we hope this insight report will support a growing movement to make Education 4.0 a universal reality.

Introduction

Before the COVID-19 pandemic, the *International Commission on Financing Global Education Opportunity* estimated that 263 million children and young people were out of school globally. Further, among those in school, many were not learning the skills needed to succeed economically in the age of the 4IR. Based on these projections, nearly one billion young people in low- and middle-income countries are not on track to acquire basic secondary-level skills by 2030.⁴ Moreover, in many parts of the world, the circumstances in which a child is born – such as gender, socio-economic status, location and ethnicity – continue to significantly influence their access to quality education. Access to quality education, or lack thereof, in turn has a strong impact on a young person’s ability to access the labour market and future economic opportunity.⁵

The COVID-19 pandemic has further exacerbated these pre-existing inequalities in education. Nearly 1.6 billion children and young people have been

impacted by COVID-19-related school closures globally. These disruptions risk having long-term implications for future socio-economic mobility, as even a four-week school closure is estimated to reduce the median learning achievement of a child by 20 percentile points.⁶ And these effects may be even more pronounced for disadvantaged students, whose families may not be able to afford other mechanisms, such as access to digital tools, for supporting continued learning during the pandemic.

The compounding effects of COVID-19 on learning inequality add to an existing financial threat to education budgets worldwide. Too often, education financing is seen as expendable and secondary to other expenditures. Attitudes towards education investment must not only work to preserve existing budget allocation for education; they should take a proactive stance in pursuing Education 4.0 skills and pedagogies (see Figure 1). One key goal of this report is to make the economic case for such a


FIGURE 1

The World Economic Forum’s Education 4.0 Framework

Content (built-in mechanisms for skills adaptation)

	Global citizenship skills To include content that focuses on building awareness about the wider world, sustainability and playing an active role in the global community.
	Innovation and creativity skills To include content that fosters skills required for innovation, including complex problem-solving, analytical thinking, creativity and system-analysis.
	Technology skills To include content that is based on developing digital skills, including programming, digital responsibility and the use of technology.
	Interpersonal skills To include content that focuses on interpersonal emotional intelligence (i.e. empathy, cooperation, negotiation, leadership and social awareness).

Experiences (leveraging innovative pedagogies)

	Personalized and self-paced learning From a system where learning is standardized, to one based on the diverse individual needs of each learner, and flexible enough to enable each learner to progress at their own pace.
	Accessible and inclusive learning From a system where learning is confined to those with access to school buildings to one in which everyone has access in learning and is therefore inclusive.
	Problem-based and collaborative learning From process-based to project and problem-based content delivery, requiring peer collaboration and more closely mirroring the future of work.
	Lifelong and student-driven learning From a system where learning and skilling decrease over one’s lifespan to one where everyone continuously improves on existing skills and acquires new ones based on their individual needs.

Source

World Economic Forum, 2020.

stance clear. Comprehensive investment strategies – locally, nationally and globally – are urgently needed to ensure primary and secondary school education systems are future-ready and equip children with the breadth of skills they need to be lifelong learners. Evidence suggests that early-childhood and primary schooling is disproportionately influential on career trajectory and lifetime earnings, laying a foundation for enabling children to “learn how to learn” throughout their lives.⁷

There is a window of opportunity to identify fundamental strategic investment in reformed primary and secondary education as part of the broader post-pandemic recovery, and re-imagine an education system that is inclusive, focuses on the skills needed to be successful in the age of the 4IR, and leverages technological and pedagogical innovation to put learners at the centre of learning. Previous work by the World Economic Forum has summarized such a vision as **Education 4.0**.⁸ As this report will document, the potential economic and social returns on such investment would be substantial – more than \$2.54 trillion in additional global GDP.

Accordingly, this report is a call to action – a call for leaders from across sectors and geographies to work together to turn the current COVID-19 learning crisis into an opportunity for education transformation.⁹ To realize this vision, stakeholders from all parts of society have a role to play – from governments and non-governmental agencies to businesses, investors and educators to parents and caregivers and learners themselves, as well as multilateral efforts such as the United Nations Transforming Education Summit planned for September 2022.¹⁰

In putting front and centre the economic case for updating and upgrading our existing education systems,¹¹ we hope this report will support a growing movement to identify opportunities for investment to make universal access to quality Education 4.0 a reality.

1

Economic returns to education: size of the prize

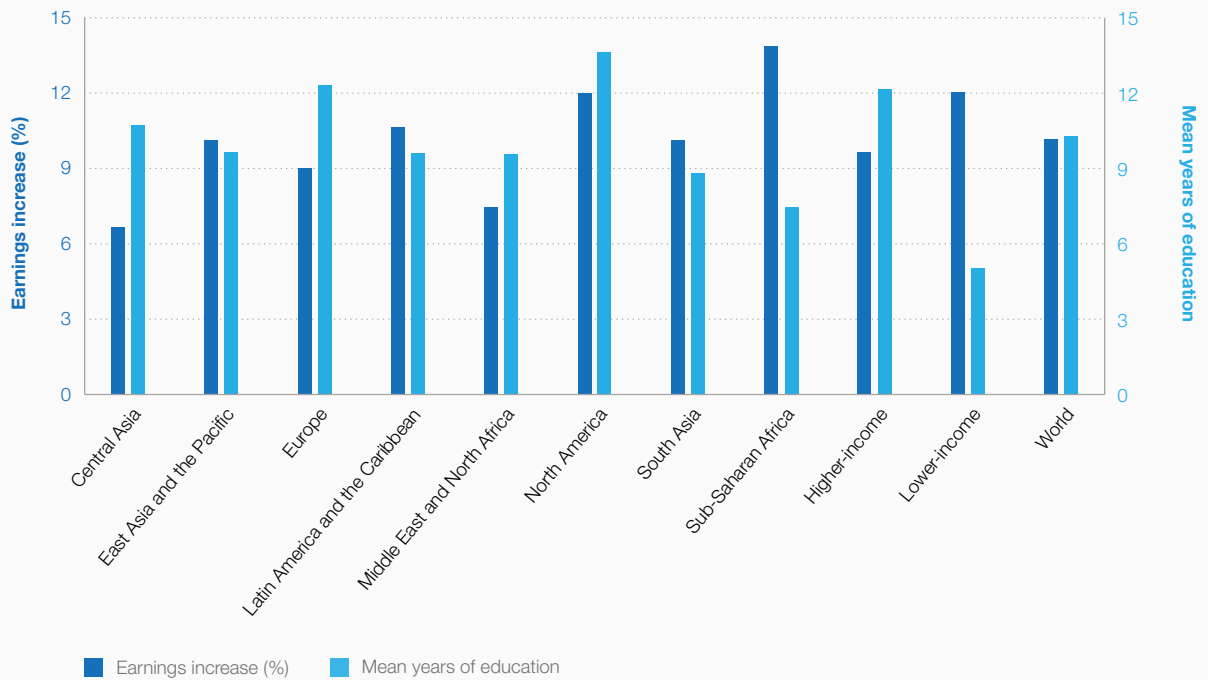
A wide range of existing research highlights the economic case for investment in education from early childhood onward. A child’s early education lays the foundation for their arc of learning throughout adult life, influencing their skill set, future employment potential and general well-being. Research suggests that early-childhood schooling and primary education have a disproportionate effect on critical cognitive development, building skills which are then multiplied through learning later in life.¹² Not only does education provide direct benefits for individuals, but these benefits elevate society as a whole by increasing health and strengthening civic institutions. The following section provides a brief overview of the existing evidence on the economic benefits of investing in education.

Individual direct returns

Data shows that a single dollar invested in education at the primary and secondary level yields an estimated \$2.50 in additional gross lifetime earnings in lower-middle income countries, and as much as \$5.00 in additional gross lifetime earnings in lower-income countries – i.e. a 500% return on investment.^{13,14} Similarly, results from studies conducted around the world indicate that an additional year of education translates to, on average, 9% higher lifetime earnings,¹⁵ and in some cases up to 15% higher (see Figure 2).¹⁶

FIGURE 2

Earnings increase due to an additional year of schooling, by region and income level



Source: World Bank, 2017, using data from Montenegro and Patrinos, 2021; World Economic Forum regional classification.

Note: Earning increase represents the median percentage increase in wages associated with each additional year of schooling.

Rates of return on education, as expressed by increase in earnings related to years of education, tend to be higher in lower-income countries than in higher-income countries (9.3% vs. 8.2%, respectively).¹⁷ As lower-income countries have lower average levels of education and lower earnings levels, investment in education thus provides the greatest benefits where it is needed most. Regionally, Sub-Saharan African countries have the highest returns at 13.9%, with rates as high as 15% for women and 9% for men.¹⁸

As economies around the world grow and gradually approach the frontier of what traditional education systems are able to provide, fully leveraging the technological and pedagogical innovations of Education 4.0 will be required to build on this foundation of direct returns and continue to contribute to the growth and development of individual well-being. The cultivation of collaborative problem-solving skills, socio-emotional awareness and other non-cognitive skills that foster innovation and creativity will be the source of much of the economic returns in the economies of tomorrow.

Macroeconomic and indirect returns

Time spent in education not only develops skills that directly lead to higher incomes for individual learners, but also measurably promotes broader economic and social well-being of individuals, communities and nations as a whole – returns that are likely to further increase in the age of the 4IR.¹⁹

Higher levels of education lead to better health, which allows individuals to lead happier, more fulfilling lives. Better health outcomes also lead to higher productivity and better economic outcomes, as healthcare costs decrease and individuals miss fewer days of work due to illness or other health conditions.^{20,21} Good health is also especially important for early cognitive development in children, which provides the foundation for skill development and success in education. Young children under three have substantial brain plasticity that readily absorbs learning experiences, laying a foundation of cognitive development that will persist throughout adulthood.^{22,23}

If we consider these indirect benefits in purely economic terms and include them in estimated rates of return to education, a single year of additional education in low-income countries rises from a return of 10.6% to 16.3%.²⁴ By some estimates, every \$1 spent on early childhood development interventions yields \$13 in economic returns.²⁵ These economic gains extend beyond the individual, as countries are able to spend a lower proportion of GDP on treating chronic health issues and a larger national talent pool is available to advance various sectors of the economy.

Education also fosters higher levels of civic engagement and institutional trust, which leads to strong institutions and effective governance. Strong institutions in turn provide the foundation for an effective business environment and, ultimately, greater economic well-being.²⁶

More years of schooling are found to be associated with more tolerant political opinions, higher rates of community volunteering and higher rates of membership of citizen groups.²⁷ One study found that individuals who had graduated from secondary schooling were 70% more likely to vote than non-graduates.²⁸ Strong civic norms inspired by robust education systems are likely to provide economic benefits in a myriad of ways, even positively impacting education systems themselves. With higher civic engagement and faith in public institutions, pro-education policies are more likely to be funded, creating a positive feedback loop for even higher levels of education in subsequent generations – in a process which culminates in higher levels of innovation, technological growth and national development.

Higher levels of education also inspire social trust by promoting lower crime rates. A study done in the United States found that if high school graduation rates increased by 1 percentage point, up to 100,000 fewer crimes would be committed the following year, leading to nearly \$2.1 billion in savings – a savings of \$3,000 per additional high school graduate.²⁹

When it comes to economic development, the education level of a nation's workforce is a fundamental driver in adopting and applying existing technologies, in pushing the technological frontier and, ultimately, in aggregate economic growth. Multi-country studies demonstrate that a variety of student achievement measures are associated with higher rates of economic growth and higher physical capital investment. For example, educational attainment accounts for 60% of worker productivity in one key study of 64 countries.³⁰ The variety of educational measures employed in the research indicate that both schooling quantity and quality are important for greater economic returns. As technological progress is a key channel through which education promotes growth, its importance is likely to increase significantly in the age of the 4IR.

One set of measures that aims to approximate key cognitive and non-cognitive skills needed to navigate future economies and thrive in the age of the 4IR is the Organisation for Economic Co-operation and Development's (OECD) *Programme for International Student Assessment (PISA)*. Recently, PISA developed an assessment of students' capacity for "collaborative problem-solving"³¹ – a concept that in many ways dovetails with the Forum's Education 4.0 framework.

To illustrate the potential economic effects of widespread adoption of Education 4.0, we estimate the returns on investment with respect to the PISA collaborative problem-solving measure, using data from the OECD and International Monetary Fund (IMF), and applying a methodology pioneered by the OECD (see Appendix).³² We estimate that a global improvement in students' collaborative problem-solving capacity to the average level of today's top 10 scoring countries could add an additional \$2.54 trillion in increased productivity to the global economy (Figure 3[a]). In absolute terms, Europe and South Asia – with potential increases of \$0.51 trillion and \$0.46 trillion, respectively – stand to benefit the most. However, relative to today's size of their regional economies, Sub-Saharan Africa and Latin America and the Caribbean also stand to benefit significantly.

At a country level, China (\$370 billion), the United States (\$242 billion), Brazil (\$145 billion), Mexico (\$82 billion) and Italy (\$75 billion) would see the highest return, in absolute terms, on such a move

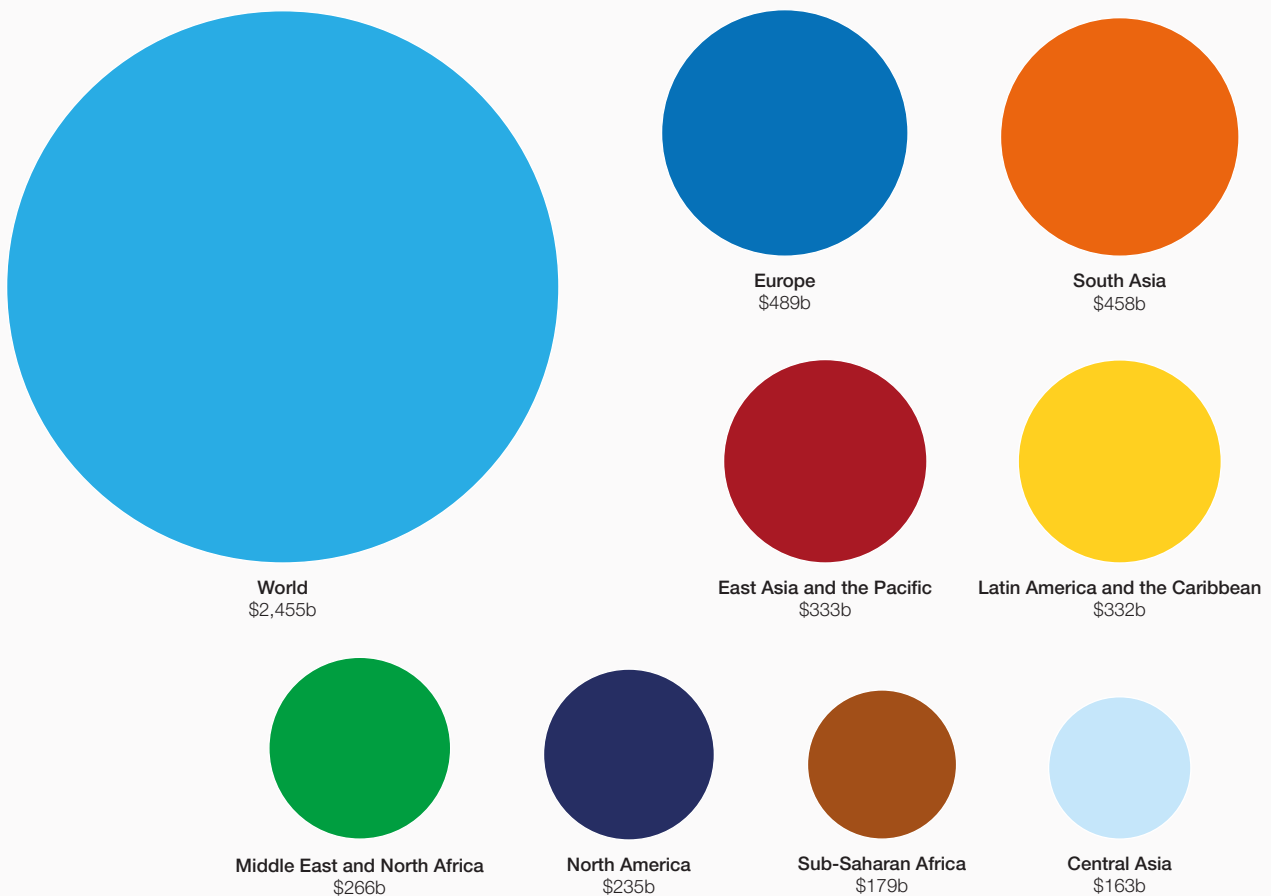
toward Education 4.0 (Figure 3[b]). However, when measured in percentage terms relative to 2019 country GDP, we see that Pakistan would earn the highest returns at 12.7% of GDP, followed by South Africa at 9.9%, Tunisia at 9.5% and Brazil at 7.6%.

The question is: What kind of education system reforms, transformations and investments would be needed to make this theoretical scenario a reality? The remainder of this report is dedicated to disentangling and documenting this economic and investment case for realizing the potential of Education 4.0. We aim to highlight key opportunity areas for investment and actions that could be taken, individually and collectively, by a variety of key stakeholders. Before we can turn to these strategies, however, it is important to consider how COVID-19, pre-existing education inequalities and accelerating technological change has affected the global playing field of education as well as today's generation of young learners.

FIGURE 3

Education 4.0: Potential GDP gain from investment in "collaborative problem solving" skills (2019 US\$, billions)

A. Region



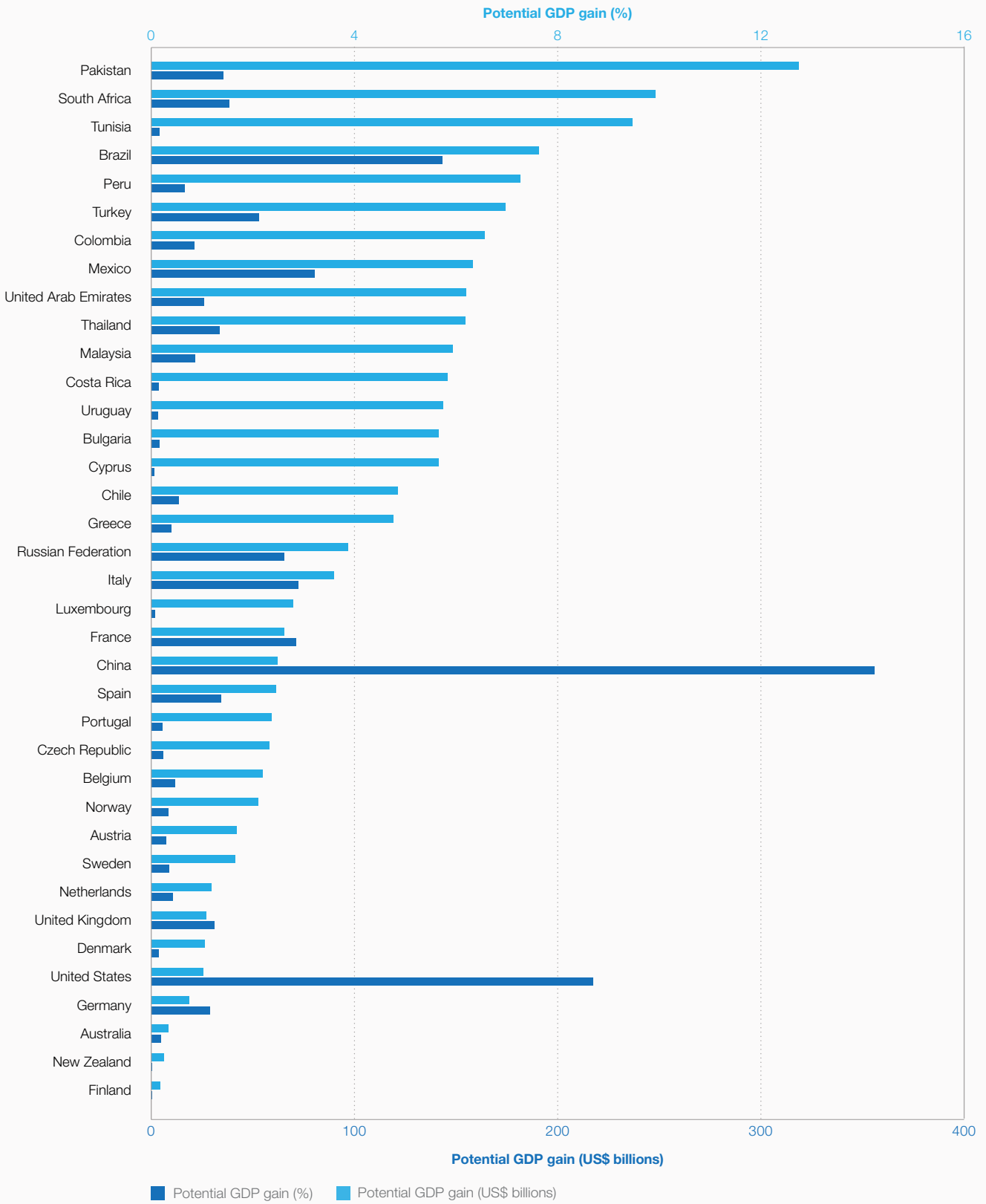
Source
World Economic Forum calculations.

Note
Projected global returns from raising PISA 2015 scores in "collaborative problem solving" to the average level of the 10 best performing countries; see Appendix for details.

FIGURE 3

Education 4.0: Potential GDP gain from investment in "collaborative problem solving" skills (2019 US\$, billions)

B. Selected countries



Source
World Economic Forum calculations.

Note
Projected global returns from raising PISA 2015 scores in "collaborative problem solving" to the average level of the 10 best performing countries; see Appendix for details.

2

Learning disrupted: education inequality, technology and the COVID-19 crisis

While upgrading education has the potential for large returns on investment, opportunities for realizing these returns are far from evenly distributed. School closures in the early months of the COVID-19 pandemic have exacerbated existing disparities in learning, and many education systems have fallen further behind in creating a workforce ready to tackle the challenges of the 4IR,³³ prompting a case for urgent change.

Education levels vary greatly within and between different countries. Not only are measured years of education very unequally distributed around the world, but the quality of education also varies considerably. A single year of education may translate to very different levels of learning in different countries. To better compare countries, experts use a measure of “learning-adjusted” years, which adjusts the measure of education for differences in quality and the rate of learning.³⁴

For this report, we construct a measure of learning-adjusted years of education by weighing standard years of education by the ratio of a country’s PISA test scores in “collaborative problem solving” to the scores of the highest-performing country (see Figure 4). To underscore the importance of Education 4.0 competencies, we again employ the measure of “collaborative problem solving” for our choice of PISA scores. When viewed through the lens of learning-adjusted years of education, inequality of education outcomes between countries appears starker than by ordinary years of education alone. Countries with high-quality education systems, such as Singapore, Japan or New Zealand, see just a small difference between actual years of education and learning-adjusted years; whereas, in many emerging economies, learning-adjusted years imply a shortfall of up to three years of education compared to actual years measured. For example, in Tunisia, average years of education fall from 10 years to only 6.8 years – a 32% drop – after adjusting for learning quality. Similarly, Cyprus, Malaysia, Peru and Brazil see almost 30% lower

measures of years of schooling after adjusting for learning quality.

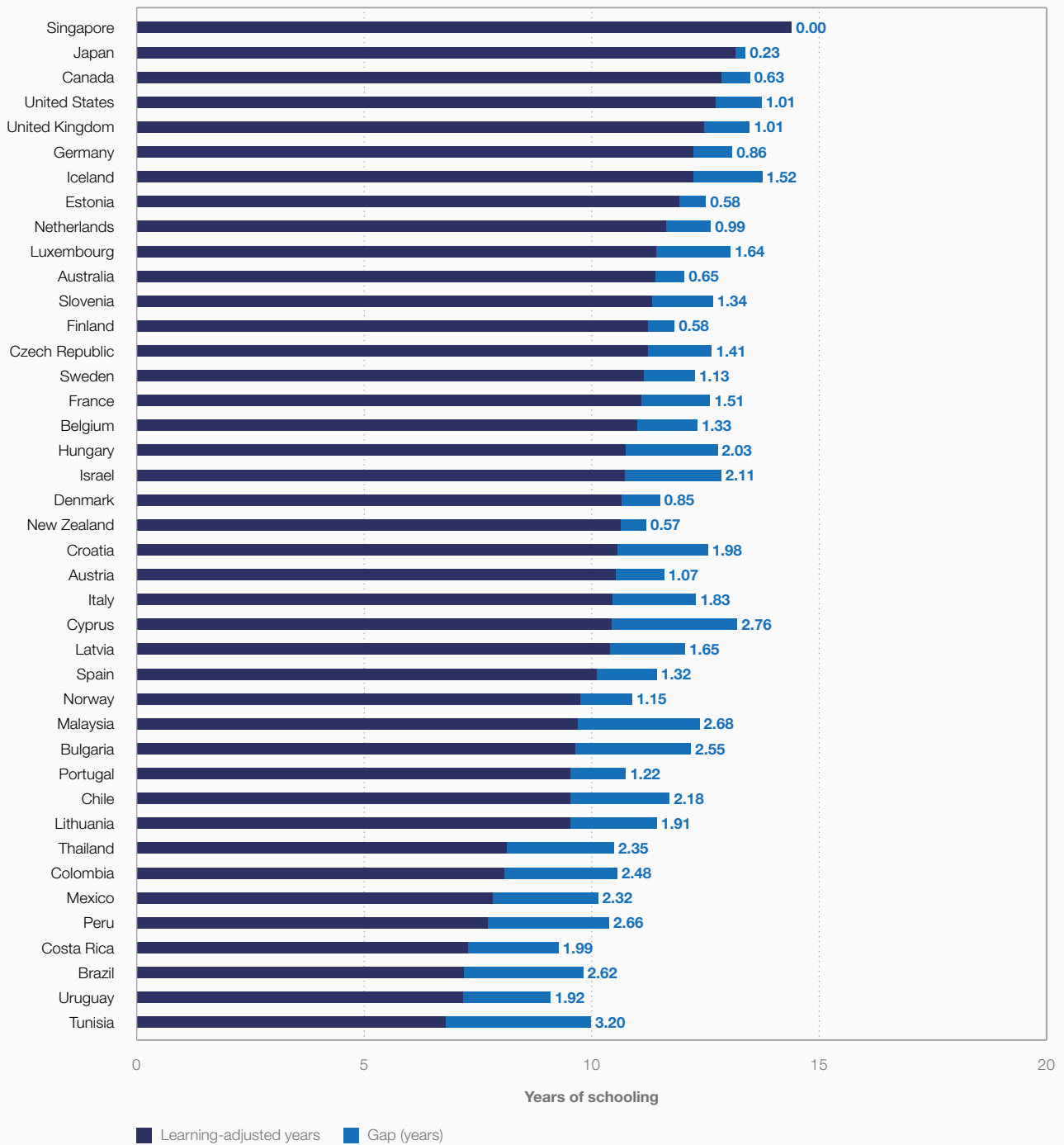
Similar disparities are highlighted by studies using cognitive skills to measure student achievement instead of years of education.³⁵ For example, by test score measures of literacy,³⁶ over 95% of the population in European countries may be considered functionally literate, compared to only 34% of the population in Brazil.³⁷ Such disparities in education and cognitive skills development also have strong implications for disparities in future economic growth. Not only do education and cognitive skills directly influence economic growth, but higher economic growth rates can lead to a feedback loop of greater resources being invested in education in the future.

These sharp disparities not only exist internationally, but also at the individual learner level, as different students are afforded different educational opportunities. As these differences accumulate over time, the status quo for returns to skills may lead to even greater levels of economic inequality.

COVID-19 has further exacerbated this learning divide. In early 2020, pandemic-related closure of schools affected an estimated 1.6 billion children and young learners in over 180 countries.³⁸ In many low- and lower-middle income countries, up to 99% of students were affected by COVID-19 related school closures,³⁹ which lasted over half of a normal school year.⁴⁰ School closures do not mean that student learning is completely halted, but it is nevertheless greatly reduced. In Germany, for example, the time children spent on school-related activities dropped from about seven to four hours per day, on average, over the course of the pandemic.⁴¹ In a study conducted in Switzerland, primary school students learned at half the rate in remote learning compared to in-person learning.⁴² And in estimates from Latin America and the Caribbean region, school shutdowns could have caused students to lose up to 88% of what they would have learned during a normal school year.⁴³

FIGURE 4

Education 4.0: gap between actual and learning-adjusted years of schooling



Source

World Economic Forum calculations, using data from World Bank, 2017, Barro and Lee, 2013, and OECD, 2015.

Note

Data compares years of actual schooling and learning-adjusted schooling among young people, ages 25-29, calculated using PISA data on "collaborative problem solving".

These losses in learning have direct economic impacts and consequences. For individual earnings, a half-year of school closure translates to an average loss of 3.9% of lifetime income across OECD countries. Among individual countries, Greece is projected to have the lowest losses, at 2.3% of lifetime income; the United States at 4.6%; and Singapore at the high end, with projected lifetime income losses of 8.4%.⁴⁴ The World Bank estimates that earnings losses could amount up

to \$17 trillion globally for the current generation of students.^{45,46} These economic losses do not only mean lower consumption and savings for individuals, but the entire economic system will slow as a consequence. In the aggregate, a half-year of learning loss is projected to result in 2.2% lower future GDP for the average OECD country.⁴⁷

Prior to the COVID-19 pandemic, education spending was on an upward trajectory, having

the strongest growth in lower-income countries. Between 2009 and 2019, global spending in real terms grew at an annual rate of 2.6%, and as high as 5.9% in low- and middle-income countries.⁴⁸ However, the onset of the pandemic has led to lost revenues, and therefore sharp cuts in spending – both in individual household spending and in government budgets. Lower-income countries have been hit the hardest by lower government spending. Since early 2020, education budgets have been cut in 65% of low- and lower-middle income countries, as well as 33% of high- and upper-middle income countries.⁴⁹

These budget cuts have affected progress towards SDG 4, whose mission is to “Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all”. Even in the pre-pandemic context, an increase to 4-6% of global GDP would have had to be allocated to education to deliver on the promise of SDG 4 by 2030.⁵⁰ With the onset of COVID-19, the prospects for achievement have worsened. Education was often de-prioritized in global economic stimulus packages, with only 2% of funding allocated toward learning, and most of that investment occurring in high-income economies.⁵¹

Moreover, in lower-income countries, a much larger proportion of education spending comes from individual household contributions – around 40% – compared to that of high-income countries, where less than 20% of education spending is contributed

by individuals. With the declines in household incomes precipitated by the pandemic, education spending in lower-income countries has suffered all the more disproportionately.

The trends outlined in this section are troubling, given the fundamental role of education in promoting economic growth and well-being. The compound effects of COVID-19, pre-existing education inequalities and the rapid technological change of the 4IR underscore the reality that simply returning to the pre-pandemic status quo risks undermining not just the life chances of today’s generation of young learners, but the very foundations of global economic recovery and future prosperity.

For any post-pandemic recovery plan to be successful and sustainable in the long term, a comprehensive approach to investment in high-quality, future-proof education systems must be a strategic priority. It is to these key opportunity areas for accelerated investment in Education 4.0 that this report will now turn.

3

Investing in education 4.0: key opportunity areas

The recovery from the COVID-19 pandemic presents a unique opportunity to rethink our approach to global educational investment. In the discussion of the pandemic’s impact on the adult workforce, it is understood that COVID-19 has led to an accelerated transformation of the labour market; of office space; and of how, where, and when work is done. Childhood and young adult education are no different.

Currently, educational investment – in developing economies in particular – is attracting relatively little capital from the private sector, blended finance or even multilateral development finance institutions.⁵² At \$5 trillion, the global education sector accounts for about 6% of global GDP, yet attracted only about \$300 billion in investments in 2020. This is less than one-tenth of the investment in the comparably-sized global healthcare sector.⁵³ Similarly, the total cumulative volume of public-private ‘blended/ impact’ investments related to UN SDG 4 over the past decade (2011-2020) stood at a modest \$1.5

billion in 2021. When compared to nearly \$16 billion in global healthcare, educational blended investment appears to be a market still very much in its infancy (Figure 5).⁵⁴ The largest and fastest-growing investments around education, by far, have been in education technology, or ‘edtech’, and are projected to attract about \$404 billion of capital globally by 2025. This push arrives notably amid increased recognition of the role of technology-enabled and remote learning during the pandemic.⁵⁵

At the same time, the education sector provides additional opportunities for job creation. While 85 million teachers are currently employed worldwide, an additional 69 million teachers will need to be recruited in the coming years to reach SDG 4.⁵⁶ Each of these roles must be supplemented with additional roles in education leadership, specialists and complementary education support roles, which will provide additional opportunities for job creation in the sector.⁵⁷

FIGURE 5

Global cumulative public-private investment related to UN SDG 4, 2011-2020



Source
Apampa, 2022, as cited in Mair, 2022.

Note
UN SDG 4: Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all.

Importantly, catalysing a new, more comprehensive investment strategy for education will require consensus among a wide range of stakeholders on what high-quality childhood education can and should actually look like. The Forum's Education 4.0 framework – developed by an intellectually diverse community of education experts, policy-makers, civil society and business leaders – provides a unified vision for childhood education that focuses on skills of the future, innovative pedagogies and learning experiences that promote inclusive and learner-

driven education.⁵⁸ Realizing this vision and making universal access to Education 4.0 a reality is a long-term endeavour that can, and must, start today.

Accordingly, this report highlights three key opportunity areas which have been evaluated to offer significant economic and social returns on investment for unlocking Education 4.0 over the coming years: new assessment mechanisms, adoption of new learning technologies and empowering the education workforce.

3.1

Opportunity area: new assessment mechanisms

Better and more data collection

According to a recent global appraisal by the World Bank, more than one-third of countries globally lack adequate data to measure reading and mathematics outcomes at the primary school level. At the secondary level, the rate is even higher – half of countries surveyed lack the necessary data.⁵⁹ There are even less mechanisms for tracking the development of holistic skills – such as global citizenship and innovation and creativity – needed for the workforce. Proper assessment mechanisms ensure that education systems attain their ultimate goal of facilitating learning. Strategic investments should be made in better tools and systems for assessing all aspects of education – the attainment of skills, the quality and relevance of curricula and pedagogy and investment needs within the education sector.

Various metrics and performance indicators could be used and should be employed in a combination of local, national and international scopes to understand cross-regional trends. International student metrics, such as the OECD's PISA data, are especially useful for benchmarking progress on skills development and can be especially relevant to tracking gaps in skills attainment. New efforts by the OECD to integrate fresh indicators focused on creativity, critical thinking and communication will be particularly helpful in assessing progress toward attaining Education 4.0,⁶⁰ albeit remaining limited in country coverage. The UNESCO Institute for Statistics has also begun publishing data on SDG Indicator 4.7.6, the "Extent to which national education policies and education sector plans recognize a breadth of skills that needs to be enhanced in national education systems," which as of 2020 hosts data for three countries.⁶¹

Similar efforts could be made to assess the effectiveness of innovative pedagogies in delivering desired Education 4.0 outcomes.⁶² Teaching approaches such as learning through play and blended learning could be highly effective for developing holistic Education 4.0 skills. Yet the propensity to focus on only assessing math and

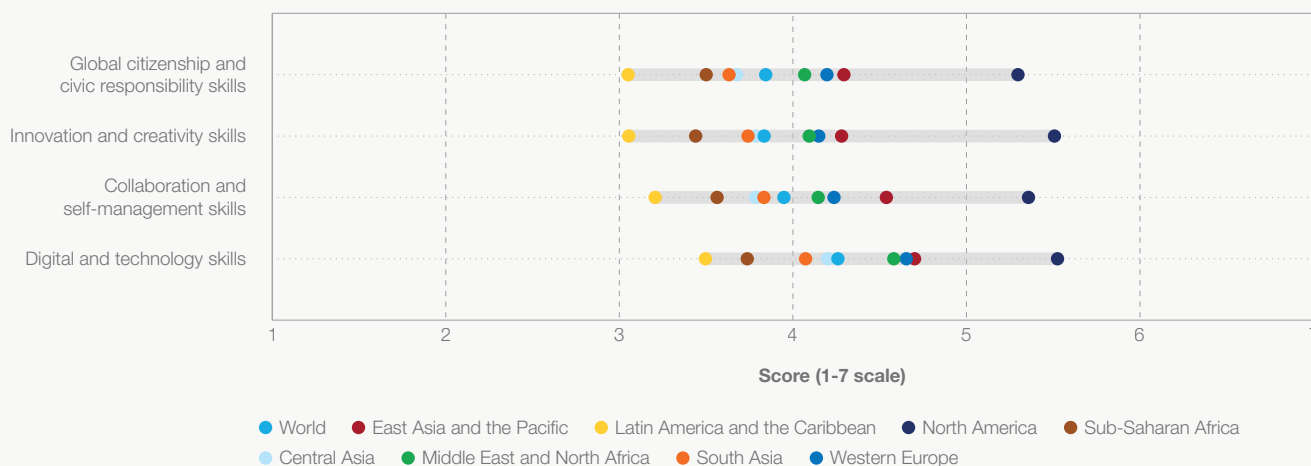
literacy outcomes undermines the power of these pedagogies to support holistic skills development.⁶³ Collecting data on the development of Education 4.0 skills can enable a better understanding of the effectiveness of new pedagogical approaches.

To contribute to the global availability of harmonized, country-level data, the World Economic Forum's annual Executive Opinion Survey also now provides data on how different countries are perceived to perform against the four skills dimensions of the Forum's Education 4.0 framework (Figure 6). The Executive Opinion Survey is disseminated to over 14,000 business leaders around the world (126 economies) and offers the advantage of capturing hiring managers' perception of workforce preparedness among several key skill areas. The survey asked executives how the current education system in their country measures up in four domains that capture the core competencies of Education 4.0: digital and technology skills, collaboration and self-management, innovation and creativity, and global citizenship and civic responsibility. Currently, North America and East Asia and the Pacific perform best on these measures, while Sub-Saharan Africa and Latin America and the Caribbean lag behind other world regions. Overall, perceptions of current workforce preparedness are highest for digital and technology skills but somewhat lower for innovation and creativity.

Additional investments should be made to ensure broad global coverage of countries for comparability and accountability on education and skills data, particularly in regions where learning data is sparse, while mechanisms should be created to track progress over time. Furthermore, metrics should emphasize cognitive and non-cognitive skill development, rather than simply time spent in education or other blunt proxies for learning. Continuous, period monitoring ensures compounded progress in learning over the early childhood years, and ultimately over a lifetime.

FIGURE 6

World Economic Forum Executive Opinion Survey assessment of the four skills dimensions of the Education 4.0 framework



Source
World Economic Forum, Executive Opinion Survey, 2021-22.

Note
Responses are to question "In your country, how well does the current education system meet the skills needs of a competitive economy? [1 = Not at all; 7 = To a great extent]" with respect to each indicated skills dimension. Data consists of 12,552 responses in total, presented as average responses by region.

New approaches to assess individuals and systems

Looking at the education system as a whole, using data that emerges from assessment exercises is critical to improving learning. Merely undertaking an assessment is not the end goal.⁶⁴ Assessment mechanisms should also track data on spending to measure return on investment of specific policies, pedagogies and approaches. Between 2018 and 2021, fewer than one-fifth of countries reported spending amounts on primary and secondary education to UNESCO or the IMF.⁶⁵ Nordic countries are some of the few that have taken strides to make public accounting and administrative data more widely available.⁶⁶ As a result, these countries are able to more closely monitor what works and what does not in their education systems.

As it relates to assessing individual skills, approaches should shift methods from summative assessments and fact recall to context-specific applications and formative assessment. Assessment mechanisms could leverage more open-ended and qualitative approaches to promote creativity and innovative thinking and to measure an individual's ability to apply a process or theory in completely new contexts. For example, a range of innovative and nuanced approaches are currently being explored with regard to assessing creativity.⁶⁷

Recent expert consensus views assessment through a lens of enabling "learning to learn" rather than testing recall of specific subjects or facts. As one author notes, "the biggest change this requires is for assessment to be viewed as an integral part of good pedagogy, rather than something that gets

tacked on at the end of the teaching cycle."⁶⁸ New education and skills assessment tools, such as self-assessment, peer-assessment, and qualitative assessment, should be leveraged to complement traditional mechanisms.⁶⁹ In the future, these may even possibly be supplemented with technology-based behavioural tools to measure cognitive, social and emotional learning.⁷⁰

Additionally, approaches adapted from workplace training and apprenticeships could serve as a more practical model for assessing learning, particularly at the secondary school level. To provide skills for the 4IR, educators should work closely with employers to understand which skills are in demand and how they are deployed in the workplace. Arguably, however, no one understands the context of skill deployment in the workplace better than employers themselves. Allowing employers to play the role of educators, for at least part of a curriculum, helps bridge the gap between learning and application. One study estimates that 5% of learned skills are firm-specific and an additional 35% are occupation-specific, meaning that up to 40% of learning is not acquired through general education programs.

Apprenticeships offer cognitive and non-cognitive skill development and motivation, learning that is guaranteed to be relevant in the workforce, and higher youth-employment rates.⁷¹ In Switzerland, for example, 70% of young people participate in an apprenticeship of some form; these apprenticeships encompass both blue- and white-collar occupations. Most participating firms see net positive benefits to investing in apprentices.⁷²

Promoting a skills-based approach

Additional measures – such as credentialization – could be adopted to enable the skills-based approach of Education 4.0. These and other tracking mechanisms should ultimately be based on cognitive and non-cognitive skills development. Measures of cognitive skills such as mathematical reasoning and language literacy are three times better at explaining economic outcomes than years of education alone.⁷³ Even for individuals with the same credentials and years of schooling, test scores are still predictive of wages.⁷⁴

Data collection, as well as evaluation mechanisms, should keep in mind the primary goal of cognitive development and step beyond measures of mere years or units completed. Many developing countries that have expanded schooling in the past decades have not seen the commensurate increases in

test scores and other measures of skill that more developed countries have experienced.⁷⁵ Schooling that provides time in the classroom without the development of analytical, reasoning, social and emotional skills has limited use.

More granular recognition, such as certifications for specific skills, skill wallets or passports, and micro-credentialing, would provide the flexibility to allow lifelong learning to accommodate more traditional degrees. Smaller-step certifications can also be substantially less costly for the learner, democratizing access to next-generation learning.

To ensure that these new assessment mechanisms remain relevant over time, a closed feedback loop between data collection, assessment and final outcomes should be established. Each of these stages in the cycle should be well-defined – and if established assessment mechanisms do not lead to desired outcomes, re-assess the assessment mechanisms.

3.2 Opportunity area: adoption of new learning technologies

Appropriate use of technology in learning

While technology itself will not lead to better quality education, advances in education technology can support more inclusive and skills-based learning and can help enhance educational processes. Furthermore, investment in the adoption of technology in learning can build resiliency into education systems so that they are able to withstand potential future shocks to the system, such as the COVID-19 pandemic.

Overall, studies of the use of technology for learning provide mixed results, indicating that technology for the sake of technology alone will not improve learning. Targeted efforts must be made to integrate technology strategically – alongside effective and innovative pedagogies – to benefit learning. For example, the well-known One Laptop Per Child (OLPC) experiment, which provided devices to students for home learning, demonstrated positive learning outcomes in the states of Maine and Texas in the United States, but no measurable educational outcomes in Brazil and Peru. More recent studies have found similarly mixed results for the educational use of smartphones.

Although many studies on information and communication technologies (ICT) use have found mixed results for formal schooling outcomes, the use of technology does teach technology literacy, which itself is an important skill for jobs of the

future. Another important area deserving additional exploration concerns the potential role of technology in fostering social and emotional learning.⁷⁶ More fundamentally, screens and digital technologies are now a consistent feature of many children's daily lives – and thus of their education and learning environments. Digital technologies can be a valuable tool in a child's development. What matters is to avoid situations in which children become passive recipients, leaving less room for creativity, personal engagement, real-life interactions and play.⁷⁷

Potentially powerful mechanisms for surfacing effective applications of appropriate use cases for technology in learning are innovation challenges such as MIT Solve and the Forum's UpLink Education Challenge (implemented in collaboration with Deloitte). The latter highlighted more than 300 submissions and provided additional scaling-up support to a shortlist of the most promising finalists.

High Tech – High Touch

A wide range of studies indicate that technology should be deployed to complement teachers, not substitute for them, and that a clear implementation plan is needed for incorporating technology for learning. Previous mixed outcomes can likely be attributed to poor implementation, and technology governance and spotting bias should be considered in any technology-driven approach to avoid unintended consequences.⁷⁸

Similarly, evidence suggests that technology is deployed most effectively when used to complement classroom teaching, not substitute for it. For example, the 'High Tech – High Touch' (HTHT) approach to learning aims to employ technology to assist in teaching the easily-defined and concrete aspects of the learning process, while reserving in-person teaching for the more abstract aspects. The method is most easily applied to the six levels of learning outlined by psychologist Benjamin Bloom. The most basic, least abstract levels of Bloom's taxonomy – remembering and understanding – can be productively addressed through personalized AI systems to maximize learning outcomes. The higher levels in the taxonomy – applying, analyzing, evaluating and creating – may then be addressed by specially trained teachers who have greater capabilities than AI systems.

HTHT has already demonstrated several successes. For example, HTHT programmes for mathematics increased student test scores in Viet Nam by 0.43 standard deviations, and in India by 0.37 standard deviations (one year of schooling is typically associated with an increase of one-third of a standard deviation). As stronger student outcomes are associated with greater economic well-being, as established earlier, the economic case for effective pedagogies is clear.

Technology for learning is especially effective for student practice and individualized learning, for example in the form of self-assessment and adaptive periodic recall drills. Learning software can provide very accurate and immediate student feedback, which can be tailored to a student's needs, and can free up time for educators to focus on instruction and qualitative feedback.⁷⁹

Catalysing future growth in education technology

With additional targeted investment, new education technologies – combined with teacher training on how to leverage these technologies to support innovative pedagogies – could offer a host of benefits as well as economic and financial returns. One recent categorization suggests five core areas of education particularly suited for application of new technologies:⁸⁰

- **Ubiquitous access:** With the wide availability of mobile devices, and especially as high-speed, next-generation networks such as 5G replace legacy systems, students, especially those in remote locations or who would otherwise have limited access to formal schooling, can be connected to ongoing lessons. For example, UNICEF's GIGA initiative aims to connect every school on the planet to the internet.⁸¹ UNICEF estimates that establishing the necessary electrical and data backbone infrastructure by

2030 could cost up to \$838 billion, while bringing down the cost of data to affordable levels could require an additional \$498 billion. Together with the costs of last-mile delivery – costs for devices, digital learning curriculum development and student engagement, totaling \$46 billion – a comprehensive endeavor to provide ubiquitous access could require nearly \$1.4 trillion in investment between 2021 and 2030.⁸²

- **Collaboration and communication:** With greater access to learning tools comes greater access to one another. Email, social media and online forums can mimic collaboration environments similar to what learners would encounter in the workplace. The playing field remains ripe for new innovations in learning collaboration. Furthermore, such technologies can also provide a mechanism to improve communication and collaboration between learners, educators and their parents. For example, apps such as ClassDojo and Remind provide two-way communication channels to share updates, photos and feedback between learners, families and educators.
- **Extended reality:** Virtual and augmented reality (VR/AR) environments – potentially including deeply immersive learning environments such as an envisioned "metaverse"⁸³ – can uniquely provide experiential learning experiences that are not easily reproduced in a classroom setting, such as 3D modeling and forms of physical learning. These simulated environments also allow students to operate in what would otherwise be dangerous environments in the real world. Moreover, innovative and playful learning pedagogies can be implemented in these virtual worlds, perhaps even more easily than they can be in the physical world.⁸⁴ According to one recent estimate, investments in VR/AR in education technologies stood at \$1.8 billion in 2018 but might reach \$12.6 billion by 2025.⁸⁵
- **Artificial intelligence:** AI systems are a key vehicle for directly applying findings from the science of learning. AI provides the possibility for adaptive learning, which tailors the learning content and pace to individual student needs. While AI systems have already been commercialized by a number of companies,⁸⁶ and deployed in programmes such as HTHT, more investment in this area is needed, including to ensure that AI-assisted learning is producing desired outcomes and avoiding algorithmic bias. According to one recent estimate, investments in AI in education technologies stood at \$0.8 billion in 2018 but might reach \$6.1 billion by 2025.⁸⁷
- **Blockchain:** Blockchain technologies are secure ledger systems, capable of executing "smart contracts" and other forms of online record keeping. Smart contracts could award credentials when learning and assessments

have been completed and could provide those credentials in a secure format to future employers. These technologies are still young, but additional investment could enable them to provide the backbone for a personalized, sovereign, and autonomous learning experience. According to one recent estimate, investments in Blockchain intelligence in education technologies stood at \$0.1 billion in 2018 but might reach \$0.6 billion by 2025.⁸⁸

Furthermore, learning sciences should be applied as new education technologies are developed, to ensure not just distribution and access to

learning technologies, but to maintain their quality and effectiveness. As these technologies are developed, children, teachers and families must continue to be centred, with the development informed by input from these key stakeholders. Moreover, specific consideration should be given to how these technologies can be leveraged to support proven pedagogies, and training needs to ensure the effective uptake of these technologies in learning. (For further reading, the Brookings report *Realizing the Promise* provides a larger collection of technologies and accompanying case studies from implementations around the world).⁸⁹

3.3

Opportunity area: empowering the education workforce

Targeted investment in educator training and innovative pedagogy development

As key stakeholders and multipliers of Education 4.0, teachers and the broader education workforce require strategic investments to ensure that they have the skills, tools and resources needed. Educator and teacher quality play a pivotal role in defining learning outcomes. In one study from the United States, researchers estimated that raising the value-added of teachers by one standard deviation would raise student lifetime incomes by \$39,000, while replacing the bottom 5% of teachers with those of average performance would increase the lifetime income of students by \$250,000 per classroom.⁹⁰

Similarly, a recent World Economic Forum study, in collaboration with PwC, found that targeted investment in upskilling the global teaching workforce could add more than \$4 billion to global GDP due to increased sector productivity.⁹¹ This includes \$1.7 billion in the United States, \$1.05 billion in China, \$310 million in Japan, \$290 million in India and \$150 million in both France and the United Kingdom, among others (see Figure 7).

Significant investments should be made in adequate training and development for educators. These efforts should be focused on long-term development of educators, rather than one-off workshops that may not provide lasting benefits for students. One of the most helpful aspects of successful teacher training is follow-up with regular sessions spaced over time. For example, one training programme for community teachers in India emphasized little preservice training but featured multiple training follow-ups and led to substantial learning gains.⁹² Training also needs to be specific, emphasizing well-defined techniques and concrete prescriptions. Abstract training that focuses on general principles is not as effective as

specific methods. Reviewing training programmes in the United States, those that focused on a specific pedagogical technique were shown to be twice as effective as those that did not.⁹³

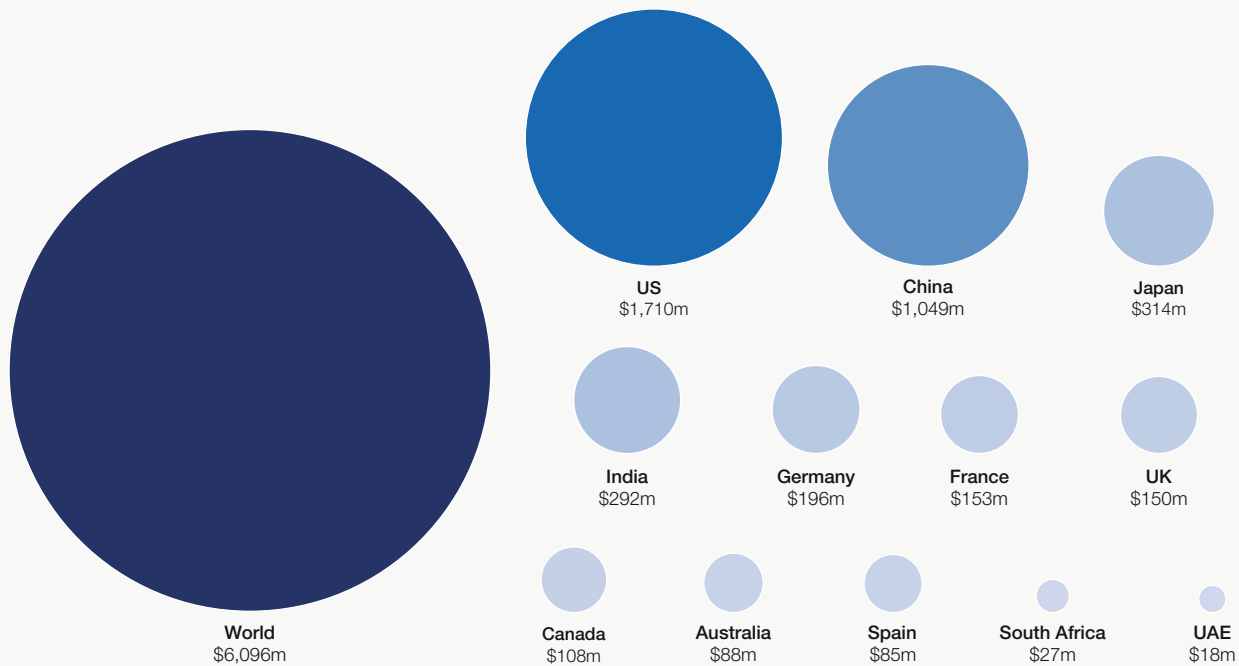
Lessons can also be learned from teacher-training programmes in Viet Nam, where learning through play has been integrated into childhood curricula alongside targeted teacher professional development on the adoption of playful learning pedagogies. In collaboration with the Vietnamese Ministry of Education and Training, VVOB-Education for Development launched a training programme for teachers based on a cycle of training, action and reflection.⁹⁴

Targeted training and development efforts should be made to support the broad implementation of innovative pedagogies, such as learning through play, blended learning, computational thinking, experiential learning, embodied learning, and gamification, which span a diversity of literacies.⁹⁵ In particular, teachers and other educators should have the freedom to create and facilitate innovative learning environments for children that incorporate a blend of child-led in addition to teacher-led experiences. A review of studies indicates that learning through play helps children develop these essential skills, while reducing pre-existing inequalities among students.⁹⁶

Implementation of learning innovation will require educators to have a mastery of pedagogical content from theory to practice, and an understanding of how to apply it to the full breadth of student diversity, reaching every student in the class – rather than focusing on the top-performing students. Furthermore, these training and development efforts should be made available to all staff within the school building – including those who are not formal teachers – to ensure that all experiences can become learning experiences.⁹⁷

FIGURE 7

Potential GDP gain from workforce upskilling in the global education sector, selected countries (2019 US\$, millions)



Source

World Economic Forum, 2021c, based on PwC UK Economics analysis.

Moreover, new Education 4.0 tools may equip teachers to better support their students for innovative pedagogies. For example, conventional practice emphasizes targeted teaching to the same difficulty standard for all students, which is typically held at a level that an average student would be able to grasp. By contrast, AI and other computer-assisted-instruction systems have shown promise in equipping teachers with the means and the tools to provide individualized learning tailored to each student's needs. In India, for example, teachers receiving assistance from dynamic learning software demonstrated higher student performance in mathematics evaluations.⁹⁸

Targeted human capital planning for the education sector

While each economy values the education sector differently – both in terms of pay and of esteem of the teaching profession⁹⁹ – the COVID-19 pandemic has underscored the role of educators as essential piece in a functioning and thriving economy. Yet, despite this realization, teachers and other educators are often underpaid, especially given the expertise that the profession ideally demands. Additional strategic efforts to recognize the education sector as critical for economic prosperity should be made. These include raising teacher pay, providing incentives for more workers to enter the education field, and providing adequate professional development opportunities.

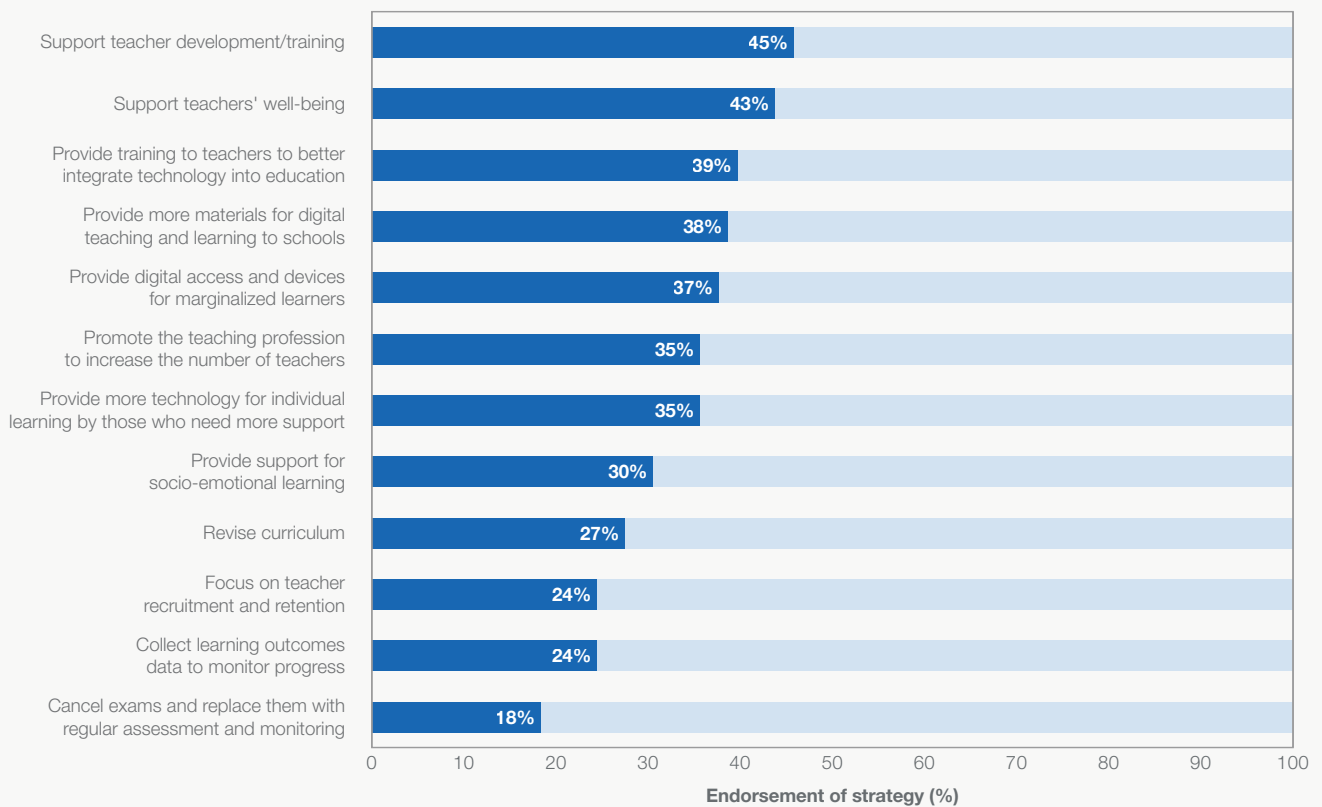
Many teachers are motivated to drive the change to promote Education 4.0 adoption. In fact, a recent global survey of teachers highlights the extent to which teachers regard their own upskilling and professional development as key mechanisms for addressing COVID-19-related learning losses, with digital training in particular ranking highly as an area for additional investment (see Figure 8).¹⁰⁰ Investment in new technologies, for instance, must be paired with proper training in those technologies in order to make the most of the investment. Teachers ultimately remain the most important player in the delivery of innovative pedagogies and other advances in the science of teaching and learning.

To facilitate more systematic education workforce planning, human capital management strategies that are typically applied in the private sector could also be applied to the education sector to anticipate potential skills gaps and ensure that individuals are placed in the roles that best match their skill sets. For example, a skills-based approach – rather than a degree-based approach – to hiring teachers could aid in matching teachers to the right students, making considerations for specific learning needs. There is, in fact, little evidence that occupational licensure has a positive effect on student learning outcomes.¹⁰¹ Furthermore, taking a skills-based approach can diversify educator talent pools to ensure that educator demographics more closely match those of their students.¹⁰²

Furthermore, additional consideration should be given to understanding complementary roles – such

FIGURE 8

Teachers' recommended strategies for addressing COVID-19 learning losses



Source
T4 Education, 2022.

Note
Response to the question: "What should governments do post-COVID-19 to address any loss of learning experienced?", %

as specialists, data analysts, workforce leaders and service providers – that could be created within the education sector to better support teacher efforts in delivering on Education 4.0 commitments. These efforts should be focused on recruiting and selecting new and diverse talent for the education workforce, and in nurturing and developing their leadership skills as they work at all levels of the ecosystem throughout their careers. New policy should be developed through consultation with a range of stakeholders, ensuring that momentum is secured across a broad base of support.¹⁰³ These roles could be a great source for job creation, but require proactive investment and planning to ensure that they deliver on their promise.

4

Call to action

Business leaders, investors, governments and educators will need to work together to make the substantial potential returns on investment in Education 4.0 a reality. Given education’s deeply embedded role in society, such a shift will require deep multi-stakeholder collaboration, changes in common expectations as well as the implementation of new policies, tools and supporting structures. The good news is that would-be innovators do not have to start from scratch or reinvent the wheel when it comes to addressing these common barriers.¹⁰⁴ Cross-country evidence suggests that there is a common set of enabling practices in education reform to which stakeholders may wish to pay close attention (Figure 9).

Moreover, businesses should also consider making dedicated visible public commitments to support education specifically.¹⁰⁵

Specific action areas include:

- **New assessment mechanisms:** Collaborate with ministries of education and educators to demonstrate the need for and co-design new assessment mechanisms, for both individual students and curricula, that are aligned to expectations regarding the future workforce. New assessments can be based on practical applications of skills in real-world scenarios that children may encounter in the workplace of the future. The private sector can provide these concrete examples for educators.
- **Adoption of new learning technologies:** Raise awareness about the potential of new technologies for skill development and work with schools and education ministries to identify high-quality digital infrastructure that supports inclusive learning and innovative pedagogies. Work with educators to demonstrate how these technologies will be used by students in their future workplaces.
- **Empowering the education workforce:** Provide opportunities for local educators to receive formal and non-formal training in skills required for the jobs of the future, with a view to ensuring classroom instruction and curricula reflect expectations in the workforce. Such training should also include a specific focus on ensuring educators have the digital skills necessary to enable Education 4.0. Furthermore, business can play a role in expanding the definition of an “educator” by working with families and communities to understand what the skills of the future are and how those can be developed from an early age through formal and informal learning.

FIGURE 9

The “secret sauce” of education reform

Enabling actions

	Defining and aligning collective values Using participatory design methodologies.
	Cultivating local agency Developing leadership capacity, empowering educators as classroom experts.
	Demonstrating reform practicality Building evidence, modelling practice, showing alignment.

Source

Barton, 2021.

This concluding section of the report highlights key enabling actions within each of the three identified opportunity areas – new assessment mechanisms, adoption of new learning technologies and empowering the education workforce – that may be taken by various stakeholders, individually or jointly, to support accelerated investment in the universal adoption of Education 4.0.

- **Business:** The private sector has an important role to play in addressing the world’s most pressing economic and social issues. As part of this responsibility, businesses should commit to investing in the education of the next generation of talent in the context of their environmental, social and governance (ESG) commitments.

- **Government:** In many countries, childhood education falls predominantly within the remit of national ministries of education (although specific ministerial portfolios vary widely from country to country). While a one-size-fits-all approach to education reform is unlikely to work, there are several common threads that – if complemented by local ownership and agency – could help unlock access to Education 4.0 for all.

Specific action areas include:

- **New assessment mechanisms:** Create skills wallets/passports that follow individuals from childhood education through to the workforce and encourage a shift in focus from formal certificates, assessments and years of education completion to specific skills development. Such wallets/passports might also help governments understand where there might be specific current or future skills gaps in national workforce development and encourage engagement and inclusion in learning across diverse populations.
- **Adoption of new learning technologies:** Co-create action plans for connecting schools in the country to the internet and accessing relevant digital tools and platforms. Furthermore, ensure that additional digital technologies in classrooms are developed with inclusive practices and common standards in skill development and in the learning experience. Critically assess how specific technologies can be adopted to support pedagogy and curricula.
- **Empowering the education workforce:** Support and provide incentives to attract highly qualified individuals to the education workforce. Recognize that learning takes place in formal and non-formal settings and provide resources for parents and extracurricular educators to help drive Education 4.0 implementation. Provide individual learning accounts to those in the education sector to continue to develop their skills. Focus training and development investments on innovative pedagogies.
- **Educators:** Education providers have an opportunity to leverage the recovery from the COVID-19 pandemic to drive fundamental reform of education systems and elevate the teaching profession as an essential element of the global workforce. There are concrete steps that educators can take to enable Education 4.0, whether collectively and globally or within the bounds of their own local classrooms.

Specific action areas include:

- **New assessment mechanisms:** Focus on the application of skills – rather than rote memorization – as measures of skill development. Use real-time data to inform pedagogy. Work with the private sector on identifying concrete examples of how broad skills will be applied in the workplace and create assessment scenarios that enable children to apply those skills.
- **Adoption of new learning technologies:** Provide feedback on new technologies as enablers of Education 4.0 and advocate for demonstrating the practicality and feasibility

of those technologies to be made available within local schools. Advocate for the technologies that can best support classroom teaching, pedagogy and communication between students, teachers and parents. Participate in focus groups for the development of new education technologies.

- **Empowering the education workforce:** Education leaders should provide teachers and others in the education sector with incentives and time to embrace and engage in lifelong learning. They might also work with local employers to understand the environments within which children will be operating once they enter the labour market and leverage these interactions to ensure curricula and learning experiences better prepare children for the future of work.

Furthermore, across all the above sectors, multi-stakeholder collaboration, such as the model presented by the World Economic Forum's Education 4.0 Alliance and Closing the Education Gap Country Accelerators – providing a platform for aligning strategic messaging and cross-stakeholder knowledge exchange – will be crucial to identify future labour market requirements in the age of the 4IR and to champion primary and secondary education models that meet those needs. Alignment will be critical around skills needed for the future of work; specific industries that will require additional talent; and the recognition of multiple and non-linear pathways from education to lifelong learning and productive employment. Crucially, such alignment must also seek to include input and local agency from youth, parents and formal and non-formal educator voices.

It is our hope that the present report will serve as a useful tool for all of these actors in highlighting and advocating for the economic case for Education 4.0 – investing in the future of learning for a human-centric recovery – and in guiding investment and enabling actions to make universal access to Education 4.0 a reality, starting today.

Appendix

Calculating potential GDP increase due to Education 4.0 adoption

For Figures 3(a) and 3(b), we present the following scenario: if all countries raise their average PISA scores in "collaborative problem solving" to the level of the average of the top 10 countries, by what amount is their annual GDP projected to increase? To answer this question, we regress GDP growth on PISA test scores and a few control variables and, given the resulting coefficient on PISA scores, we estimate how much the implied required rise in PISA scores increases GDP growth. We then project this increase in growth on actual 2019 GDP to estimate the corresponding dollar amount by which GDP would increase. The procedure we use for calculating potential GDP increase is as follows:

1. GDP growth rates from 2010 are regressed on PISA test scores for "Collaborative Problem Solving" from 2015, and controls for GDP per capita in 1990 and average years of schooling attainment in 1990. This is inspired by the regression used in OECD (2010), in which the authors regress average per capita growth rates from 1960 to 2000 on an aggregate country PISA score index, and controls for GDP per capita in 1960 and average schooling attainment in 1960. We use controls from 1990 instead of 1960 as this allows us to expand our country sample to a greater number of geographical regions (as for some regions, earlier data on growth rates is not available). The coefficient (response) on PISA scores is used to predict the increase in GDP growth due to a given increase in PISA scores (step 2). We substitute Trends in International Mathematics and Science Study (TIMSS) mathematical scores in place of PISA scores for South Africa and Pakistan, as PISA scores for "collaborative problems solving" are not available for any country in the Sub-Saharan Africa or South Asia regions.
2. We consider the scenario in which all countries increase PISA scores for "collaborative problem solving" to a target level, that level being the average of top 10 country averages (for the same "collaborative problem solving" PISA score). The top 10 countries are: Australia, Finland, Germany, Hong Kong SAR, Japan, Macao SAR, New Zealand, Singapore, South Korea and the United States. The mean score for this group is 537. We then find the "delta" in PISA scores that countries would need to reach the target level by calculating differences between the target and the countries' actual scores. This delta value will inevitably be slightly negative for the few countries above the target threshold, and while their GDP projections are included in the final analysis, their data points are not presented in the country-level data visualizations.
3. We multiply the required delta in PISA scores (to reach the target) by the coefficient on PISA scores (obtained from the earlier regression), to yield a prediction for change in GDP growth rate for each country (which is positive, except for the few countries that have PISA scores above the target mean of countries in the top quintile).
4. For country-level GDP projections, this growth rate projection is multiplied by the country's 2019 GDP to obtain a projection for change in GDP.
5. For regional GDP projections, we take the simple average of country-level predicted GDP growth rates by region, using the countries present in the regression sample. We multiply this regional average by 2019 regional aggregate GDP, which was obtained from the World Bank and based on the aggregation of country-level GDP from an extensive list of 206 countries.

Endnotes

1. The 4IR builds on the innovations of steam power and primary production of the First Industrial Revolution, the proliferation of electricity and mass manufacturing of the Second Industrial Revolution, and more recently the advances in computers and electronic devices in the Digital Revolution. The 4IR refers to the current wave of advances in data collection and information processing, including cloud computing, ubiquitous wireless internet access, artificial intelligence and biotechnology, to name a few domains.
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6. Eyles, et al, 2020.
7. Heckman, 2006.
8. World Economic Forum, 2020.
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12. Heckman, 2006.
13. Based on the relationship between years of education and earnings, in a sample of 92 lower- and lower-middle-income countries.
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15. Psacharopoulos and Patrinos.
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17. Psacharopoulos and Patrinos, 2018.
18. World Bank, 2017.
19. Ra, et al, 2021.
20. Lochner, 2011.
21. Schäferhoff, et al, 2016.
22. Harvard University Center on the Developing Child, 2007.
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24. Schäferhoff, et al, 2016.
25. World Health Organization, 2018.
26. World Bank, 2017.

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27. Lochner, 2011.
28. World Bank, 2017.
29. 2008 dollars. See Lochner, 2011.
30. Woessmann, 2003.
31. See <https://www.oecd.org/pisa/innovation/collaborative-problem-solving/> for more details on this assessment.
32. In short, we find an association between average “collaborative problem solving” scores and country GDP growth. We calculate the increase in scores each country would require to reach the level of the average of the top 10 scoring countries. This score increase can then be equated to a GDP growth rate, using the association found in the first step. We multiply the estimated increase in growth by actual 2019 GDP to yield a projection for GDP increase at the country level. The procedure is repeated for regional projections by averaging the projected country growth by region and multiplying by aggregate 2019 regional GDP. See Appendix for detailed procedure. Note that 2015 PISA scores for “collaborative problem solving” are the most recent available for this measure.
33. Ra, et al, 2021.
34. World Bank, 2017.
35. Angrist, et al, 2021.
36. Functional literacy corresponds to a score of 400 or more on the PISA literacy test, which is roughly equivalent to one standard deviation below the OECD mean. See Hanushek and Woessmann, 2008.
37. Hanushek and Woessmann, 2008.
38. Azevedo, 2020.
39. United Nations, 2020.
40. UNESCO, 2021a.
41. Hanushek and Woessmann, 2020.
42. Tomasik, et al, 2020.
43. World Bank, 2020.
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45. World Bank, 2020.
46. International Bank for Reconstruction and Development, The World Bank, UNESCO and UNICEF, 2021.
47. Hanushek and Woessmann, 2020.
48. World Bank, 2021.
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50. UNESCO, 2015.
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52. Mair, 2022.
53. HoloniQ, World Bank, World Health Organization, S&P Global, as cited in: HoloniQ, 2021.
54. Apampa, 2022, as cited in: Mair, 2022. There are a variety of reasons for this, including COVID-19-related public budget cuts; fragmentation of the sector resulting in comparably small deal size for UN Sustainable Development Goal 4 oriented investments by institutional investors such as pension funds and insurance companies; and open questions regarding the appropriateness of one such type of investment – for-profit school models in developing economies.
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73. They explain three times the variation in the data. See Hanushek and Woessmann, 2008.
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Sources

GDP growth rates are from the World Bank (2022).

Regional aggregate GDP for 2019 is from the World Bank (2022).

PISA test scores are from OECD (2015).

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