WORLD ECONOMIC FORUM

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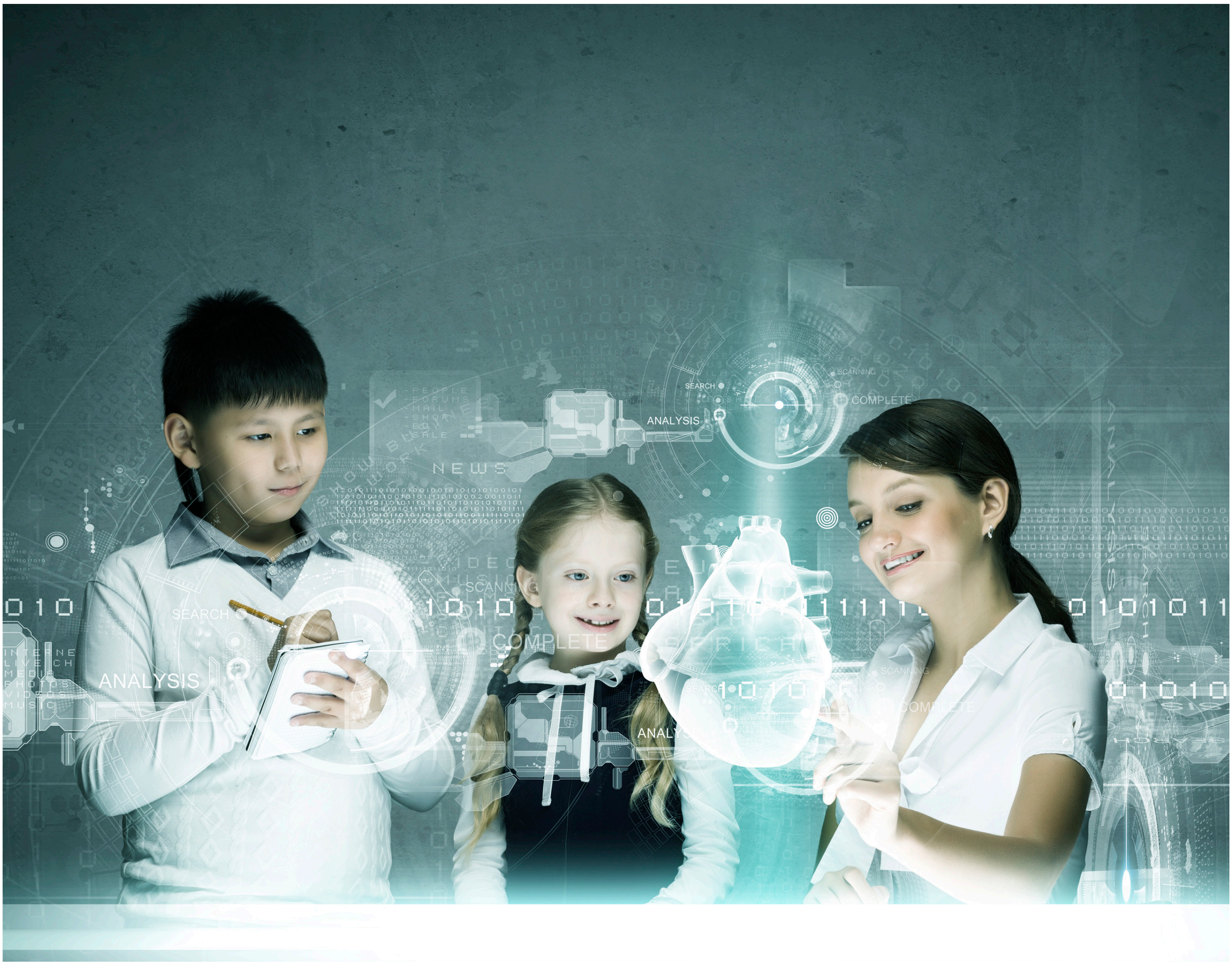
Industry Agenda

New Vision for Education

Unlocking the Potential of Technology

Prepared in collaboration with The Boston Consulting Group



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Executive summary

To thrive in a rapidly evolving, technology-mediated world, students must not only possess strong skills in areas such as language arts, mathematics and science, but they must also be adept at skills such as critical thinking, problem-solving, persistence, collaboration and curiosity. All too often, however, students in many countries are not attaining these skills. In this context, the World Economic Forum has taken on a multi-year initiative, New Vision for Education, to examine the pressing issue of skills gaps and explore ways to address these gaps through technology.

In this report, we undertook a detailed analysis of the research literature to define what we consider to be the 16 most critical "21st-century skills". Our study of nearly 100 countries reveals large gaps in selected indicators for many of these skills – between developed and developing countries, among countries in the same income group and within countries for different skill types. These gaps are clear signs that too many students are not getting the education they need to prosper in the 21st century and countries are not finding enough of the skilled workers they need to compete.

In response, numerous innovations in the education technology space are beginning to show potential in helping address skills gaps. These technologies have the potential to lower the cost and improve the quality of education. In particular, we found that education technology can complement existing and emerging pedagogical approaches such as project-based, experiential, inquiry-based and adaptive learning methods. In addition, education technology can be uniquely deployed to facilitate the teaching of 21st-century skills such as communication, creativity, persistence and collaboration.

Given the early stages of technology adoption, however, we acknowledge that its full potential to have an impact on student learning in primary and secondary education has yet to be realized. We also appreciate that education technology is only one potential component of the solution to the challenges facing education throughout the world. We have found that education technology can yield the best results if it is tailored to a country's unique educational challenges, such as those related to inadequately trained teachers or insufficient financial resources, among others.

Our survey of educational technology trends revealed that much more can be done to develop higher-order competencies and character qualities, to align technologies with learning objectives and to develop learning approaches that efficiently and comprehensively deploy technology throughout the stages of instruction and learning.

In this report, we argue that for technology to reach its greatest potential it needs to be better integrated into an instructional system we call the "closed loop". For instance, at the classroom level, education technologies should be integrated within a loop that includes instructional delivery, ongoing assessments, appropriate interventions and tracking of outcomes and learning. At the system level, which can include countries, districts and school networks, we argue that technology can be factored into the broader educational policy decisions that align standards and objectives with 21st-century skills.

We have identified an illustrative set of instructional and institutional resources and tools that further strengthen the instructional system and support the closed loop. Examples of these include personalized and adaptive content and curricula, open educational resources and digital professional development tools for teachers. We also reference three distinct school networks from different parts of the world to illustrate how technology is being deployed to address challenges unique to local country contexts.

Delivering on a technology-enabled closed-loop instructional system – one that will help close the 21st-century skills gap – will ultimately require effective collaborations among a complex and interconnected group of policy-makers, educators, education technology providers and funders. When implemented thoughtfully, these collaborations can begin to bring the most effective education technologies to more of the world's students in an effort to address 21st-century skills gaps.

Chapter 1: The skills needed in the 21st century

To thrive in today's innovation-driven economy, workers need a different mix of skills than in the past. In addition to foundational skills like literacy and numeracy, they need competencies like collaboration, creativity and problem-solving, and character qualities like persistence, curiosity and initiative.

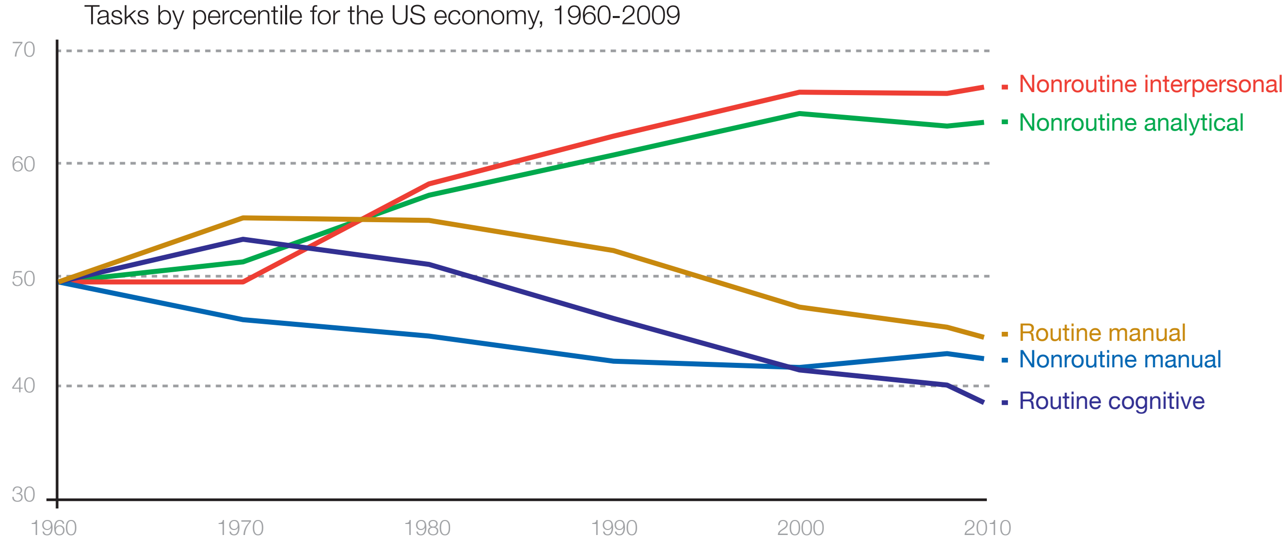
Changes in the labour market have heightened the need for all individuals, and not just a few, to have these skills. In countries around the world, economies run on creativity, innovation and collaboration. Skilled jobs are more and more centred on solving unstructured problems and effectively analysing information. In addition, technology is increasingly substituting for manual labour and being infused into most aspects of life and work. Over the past 50 years, the US economy, as just one of many developed-world examples, has witnessed a steady decline in jobs that involve routine manual and cognitive skills, while experiencing a corresponding increase in jobs that require non-routine analytical and interpersonal skills *(see Exhibit 1)*. Many forces have contributed to these trends, including the accelerating automation and digitization of routine work.

The shift in skill demand has exposed a problem in skill supply: more than a third of global companies reported difficulties filling open positions in 2014, owing to shortages of people with key skills.[1] In another example, across the 24 countries included in the Programme for the International Assessment of Adult Competencies (PIAAC), an average of 16% of adults had a low proficiency in literacy and an average of 19% had a low proficiency in numeracy.[2] Only an average of 6% of adults demonstrated the highest level of proficiency in "problem-solving in technology-rich environments."[3]

To uncover the skills that meet the needs of a 21st-century marketplace, we conducted a meta-analysis of research about 21st-century skills in primary and secondary education. We distilled the research into 16 skills in three broad categories: *foundational literacies*, *competencies* and *character qualities*[4] *(see Exhibit 2; see also Appendix 1 for definitions of each skill).*

- *Foundational literacies* represent how students apply core skills to everyday tasks. These skills serve as the base upon which students need to build more advanced and equally important competencies and character qualities. This category includes not only the globally assessed skills of *literacy* and *numeracy*, but also *scientific literacy*, *ICT literacy*,[5] *financial literacy* and *cultural and civic literacy*. Acquisition of these skills has been the traditional focus of education around the world. Historically, being able to understand written texts and quantitative relationships was sufficient for entry into the workforce. Now, these skills represent just the starting point on the path towards mastering 21st-century skills.

Exhibit 1: The labour market increasingly demands higher-order skills



Note: The starting point of the chart has been indexed to 1960.
Adapted from Levy, Frank and Richard J. Murnane. "Dancing with robots: Human skills for computerized work." Third Way NEXT. 2013. (http://content.thirdway.org/publications/714/Dancing-With-Robots.pdf) Data provided by David Autor at MIT and updated from the original 2003 study by Autor, Levy and Murnane.

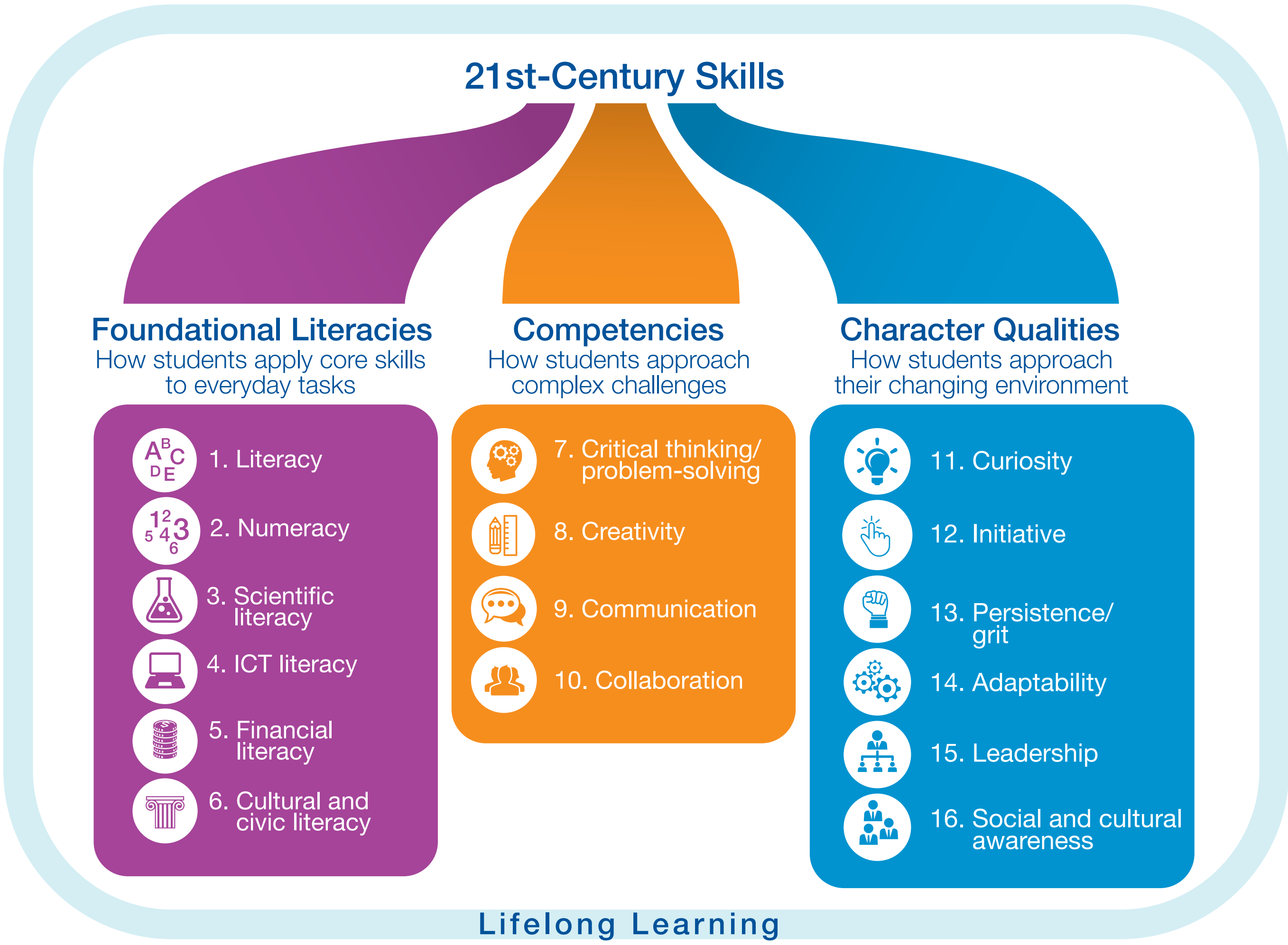
[1] "The Talent Shortage Continues: How the Ever Changing Role of HR Can Bridge the Gap." Manpower Group. 2014. (http://www.manpowergroup.com/wps/wcm/connect/manpowergroup-en/home/thought-leadership/research-insights/talent+shortage/talent+shortage#.VMvTyjt0xVc)
Note: Manpower Group interviewed more than 37,000 employers in 42 countries in the first quarter of 2014 and found that on average 36% reported having difficulty filling jobs, the highest proportion in seven years.
[2] "Low proficiency" corresponds to adults performing at level 1 (the lowest proficiency level) or below.
[3] "OECD Skills Outlook 2013: First Results from the Survey of Adult Skills." Programme for the International Assessment of Adult Competencies (PIAAC). Organisation for Economic Co-operation and Development. 2013. (http://www.oecd.org/site/piaac/surveyofadultskills.htm)
[4] We referenced frameworks from European Skills, Competences, Qualifications and Occupations (ESCO), Partnership for 21st-Century Skills, enGauge, Brookings and Pearson.
[5] ICT stands for information and communications technology.

- *Competencies* describe how students approach complex challenges. For example, *critical thinking* is the ability to identify, analyse and evaluate situations, ideas and information in order to formulate responses to problems. *Creativity* is the ability to imagine and devise innovative new ways of addressing problems, answering questions or expressing meaning through the application, synthesis or repurposing of knowledge. *Communication* and *collaboration* involve working in coordination with others to convey information or tackle problems. Competencies such as these are essential to the 21st-century workforce, where being able to critically evaluate and convey knowledge, as well as work well with a team, has become the norm.
- *Character qualities* describe how students approach their changing environment. Amid rapidly changing markets, character qualities such as *persistence* and *adaptability* ensure greater resilience and success in the face of obstacles. *Curiosity* and *initiative* serve as starting points for discovering new concepts and ideas. *Leadership* and *social and cultural awareness* involve constructive interactions with others in socially, ethically and culturally appropriate ways.

While all 16 of these skills are important, we have observed little consistency in their definition and measurement. This is especially true for competencies and character qualities. The lack of comparable indicators poses a challenge for policy-makers and educators in measuring progress globally. Another problem is that most indicators focus on foundational literacies, while the development of indicators measuring competencies and character qualities still remains at an early stage. In addition, differences in scores between some competencies and character qualities, such as creativity, initiative and leadership, are likely influenced by cultural factors and as such may be difficult to compare. For seven skills within competencies and character qualities we were unable to make any comparisons due to the absence of comparable data at scale, even for the more developed countries of the Organisation for Economic Co-operation and Development (OECD). It is of crucial importance that measures for these skills be developed and tracked in the future. *(See Appendix 2 for a discussion of the challenges of measuring performance across countries, as well as Appendix 3 for the sources used in this report for each indicator.)*

Much more needs to be done to align indicators, ensure greater global coverage for key skills, establish clear baselines for performance integrated with existing local assessments, standardize the definition and measurement of higher-order skills across cultures and develop assessments directed specifically towards competencies and character qualities.

Exhibit 2: Students require 16 skills for the 21st century



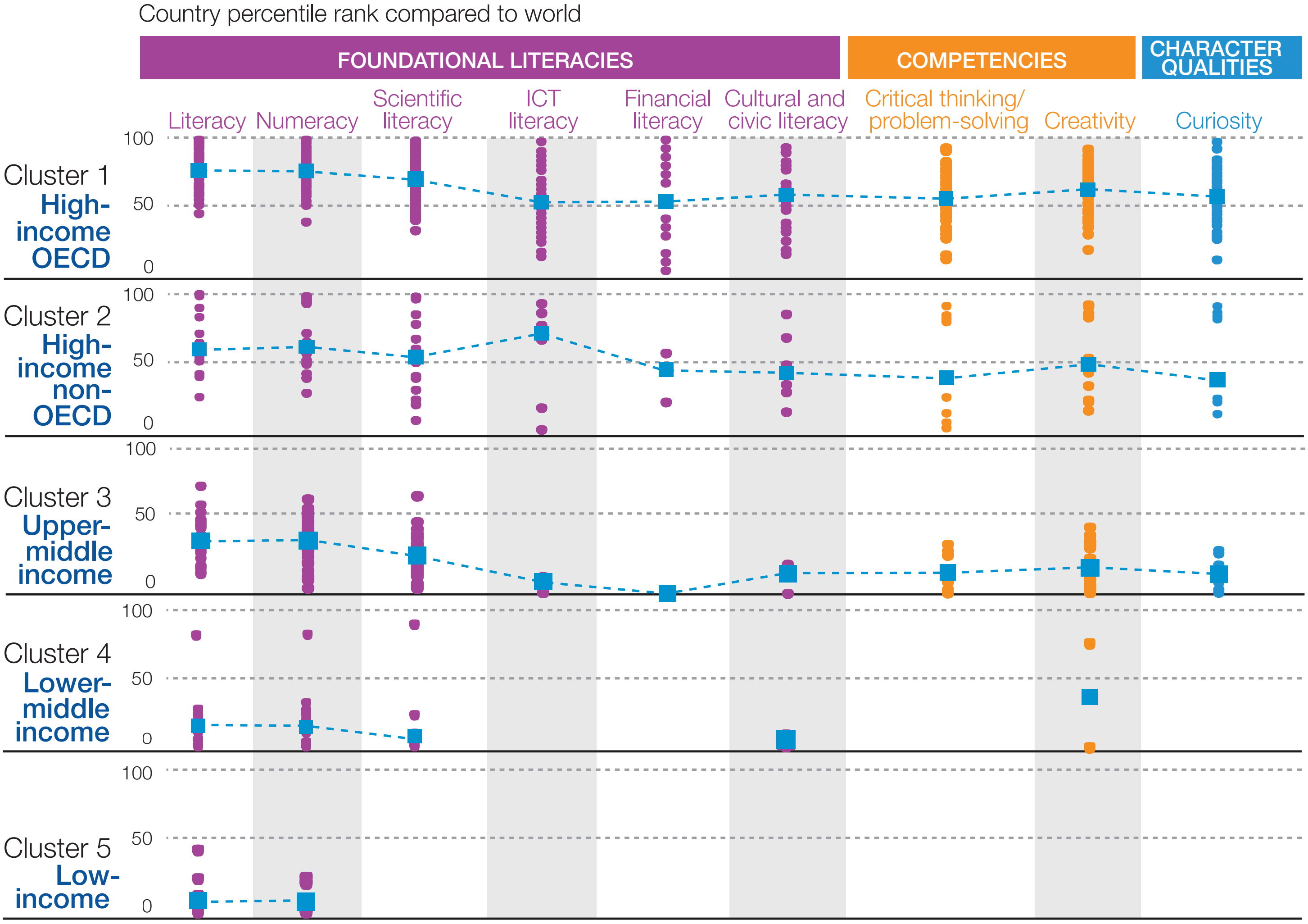
Chapter 2: The 21st-century skills gap

An in-depth analysis of performance indicators across 91 countries has found stark differences for different skill types not only across income clusters, as defined by the World Bank, but also within the same income cluster and within countries. While the differences are most pronounced between developed and developing countries, we also found wide variations in performance among high-income countries. In addition, we found differences within countries in terms of performance on foundational literacies versus higher-order competencies and character qualities.

Starting with differences between developed and developing countries, we found that higher-income countries in the OECD – which includes developed countries such as the United States, Germany, Japan and the United Kingdom – tend to perform much better on average across most skills than developing countries in the upper-middle-income group, which includes countries such as Brazil, Malaysia, South Africa and Turkey *(see Exhibit 3; Appendix 4 includes the members of each income group)*. For instance, median performance for upper-middle-income countries in our sample on the 2012 literacy test by the Programme for International Student Assessment (PISA) was 416, while high-income OECD countries scored significantly higher at 499.

While broad differences between high-income OECD countries and upper-middle-income countries can be discerned, it can be much more challenging to draw comparisons between these income clusters and lower-middle and low-income clusters. Virtually none of the lower-income countries take part in comparable tests such as PISA. A high-level analysis of regional tests, such as the Southern and Eastern Africa Consortium for Monitoring Educational Quality (SACMEQ), does allow a ranking comparison inclusive of some lower-income countries for literacy and numeracy *(see Appendix 5 for a comparison of data across three tests we used in this report)*. The analysis confirms that higher-income countries do indeed perform better. However, notable exceptions exist, such as Vietnam, which ranks on par with Germany and ahead of France on literacy, and Tanzania, which ranks ahead of Brazil, Malaysia, Indonesia and South Africa on literacy in our sample. These exceptions show that income is only one of many factors affecting educational outcomes. As such, it is important to holistically evaluate unique country contexts when devising solutions to address skills gaps.

Exhibit 3: A wide variation in skills exists within countries and among income groups



Source: World Bank income clustering for 91 sample countries. See Appendix 3 for select indicators behind each skill. Note that for some skills there were very few data points.

Context matters

Underlying the skills gap are significant macro-level issues that impede learning. These factors include fundamental economic and social problems, such as poverty, conflict, poor health and gender discrimination. Progress in addressing the 21st-century skills gap cannot be made without tackling these basic elements.

In addition, we identified four key country-level educational areas in which many countries outperform or underperform *(see Appendix 3 for the indicators used to measure them and the challenges in doing so)*:

1. **Policy enablers:** Standards that govern K-12 education
2. **Human capital:** Teacher quality, training and expertise
3. **Financial resources:** The importance of education in public budgets
4. **Technological infrastructure:** Access to new digital tools and content via the internet

Deficiencies in each of these areas disproportionately affect low-income countries. Exhibit 4 explores how five income groups rate on these educational factors. For example, lower-income countries rank in the bottom quartile of our sample (the median rank is in the 26th percentile) in terms of the number of students per trained teacher in primary school – a proxy measure of human capital – compared with high-income countries, which tend to have many more trained teachers (the median rank is in the 86th percentile). Similarly, wide disparities can be seen in the other indicators.

The issues also manifest themselves in different ways: some educational systems face high teacher absenteeism, while others have too many teachers who have not mastered the content they are required to teach, for example. Each country and culture therefore requires unique solutions.

Technology has a role to play in addressing some of these contextual factors. The Varkey Foundation, through its Making Ghanaian Girls Great (MGCubed) project, is an example of an organization working around the constraints of human capital with the help of technology.[6] Since 2013, the project has established a network of 72 state schools in two regions of Ghana to improve access to education through satellite-based interactive distance learning. The project provides daily English and mathematics classes and aims to reach more than 3,000 marginalized girls. The project is supported by the UK government's Department for International Development, as part of its Girls' Education Challenge.

MGCubed equips each classroom with a satellite dish and technology hardware powered by solar energy to combat the challenges of poor electricity and internet infrastructure. Through a high-speed satellite broadband connection, the project connects each classroom to a professional TV studio based in the capital city of Accra, where master teachers deliver lessons across multiple classrooms to up to 1,000 students at a time. The interactive system enables master teachers to take questions in real time from students working with their own teachers, who facilitate the learning in local classrooms.

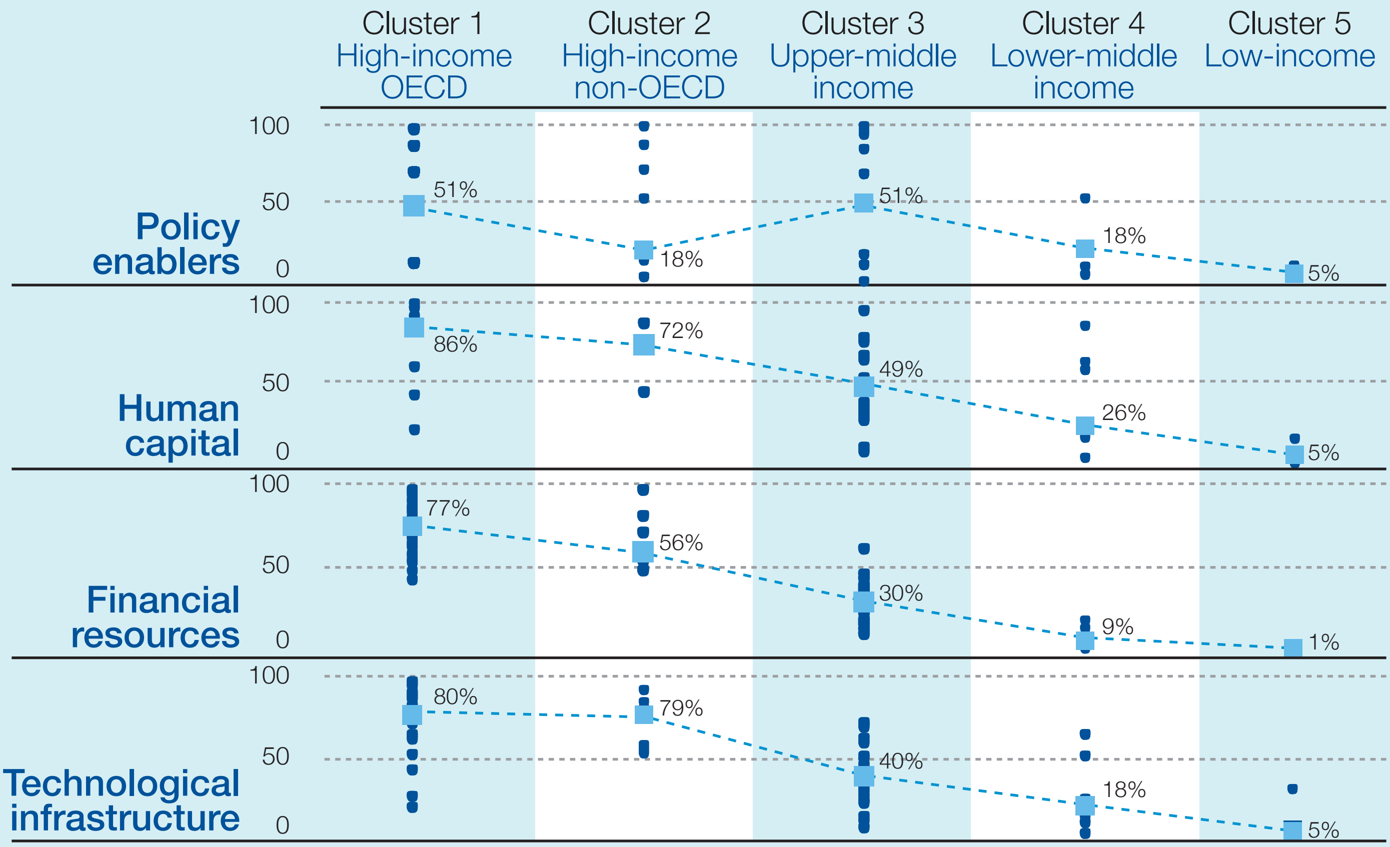
The project helps address endemic problems with teacher quality and absenteeism, which can be as high as 35% in some regions of the country, according to the organization. Local teachers in each of the network schools also receive technology and teacher training to participate in the programme. Over time, the project aims to instill some of the teaching practices modeled by the project's master teachers in local teachers.

The MGCubed project's results will be tightly monitored – the pilot is undergoing an independent randomized control trial to evaluate its outcomes and effectiveness – providing intelligence about the extent that distance-learning projects can transform the prospects for girls who participate, as well as whether it can be replicated across Africa.

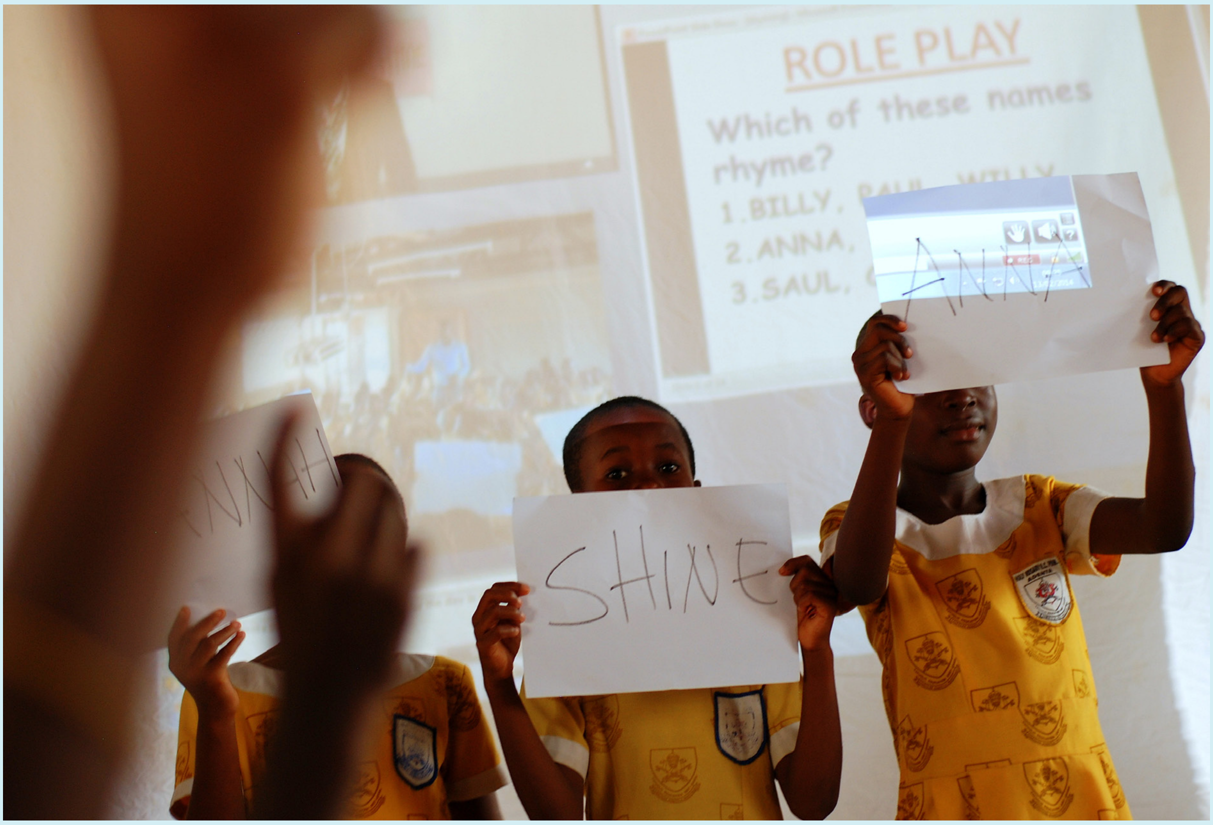
[6] The Varkey Foundation is the philanthropic arm of GEMS Education, which designed the pilot.

Exhibit 4: Four key factors are holding countries back

Country percentile rank compared to world



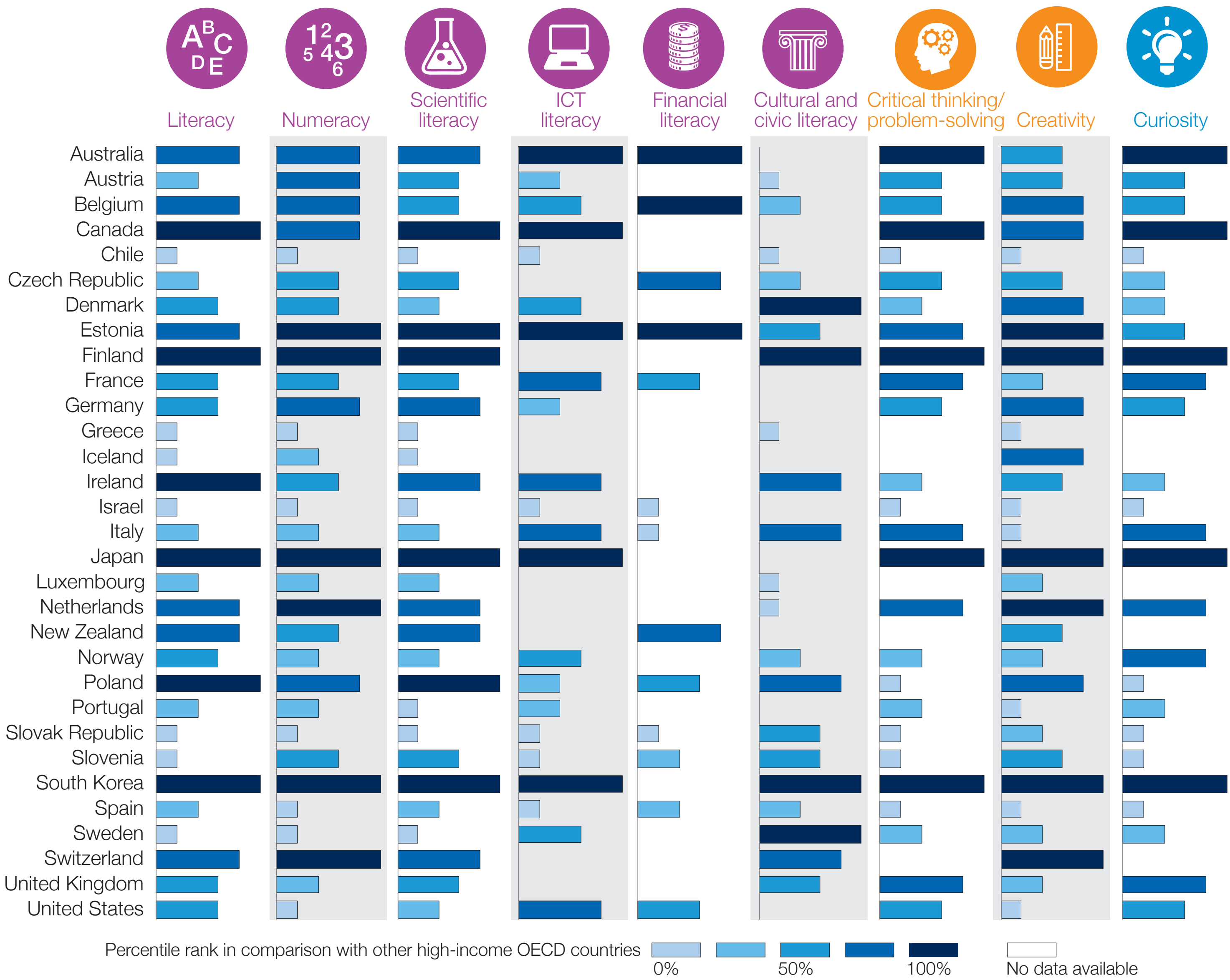
Source: World Bank income clustering for 91 sample countries. See Appendix 3 for select indicators behind each skill. Note that for some skills there were very few data points.



Source: GEMS Education Solutions.

Exhibit 5: Skills vary widely among wealthy countries

A comparison of select skill indicators among a sample of high-income OECD countries



Source: World Bank income clusters. See Appendix 3 for the skill indicators used.

Broad differences in performance based on income make intuitive sense. More surprising are the wide variations in skills performance within even high-income clusters. Exhibit 5 shows skills gaps when high-income OECD countries are compared to each other.

As one high-profile example, the United States performs relatively well on most skills when compared with the entire world. But when compared with high-performing peers such as Japan, Finland or South Korea, the United States shows significant gaps in numeracy and scientific literacy. The United States ranked 36th out of 65 countries that took the 2012 PISA mathematics test (with a score of 481) and 28th out of 65 countries on the 2012 PISA science test (with a score of 497), for instance, compared with Japan's 2012 ranking of 7th in mathematics (a 536 score) and 4th in science (a 547 score).

In addition to gaps found vertically between countries, horizontal gaps also exist within the same country. At an individual country level, a gap exists between foundational literacies and competencies and character qualities such as critical thinking, creativity and curiosity. For example, Poland performs well on a range of indicators representing foundational literacies, even while displaying gaps in critical thinking/problem-solving and curiosity. Similarly, Ireland stands out in terms of foundational skill indicators relative to other OECD countries, but shows gaps when compared to peers on critical thinking/problem-solving, creativity and curiosity.

Some income clusters display strong performance across all skills. For example, Canada, Finland, South Korea and Japan are among the top performers within the high-income OECD group on all skills.

Chapter 3: The potential of technology to help close the skills gap

Numerous innovations in the education technology space are beginning to show potential in improving education and helping address skills gaps. To help lower the cost and improve the quality of education, education technology is being used to:

- Find creative solutions to fundamental challenges in many countries, such as a lack of well-trained teachers and broadly accessible technology infrastructure
- Make education available to a broader audience at a much lower cost or provide higher quality instruction at the same price
- Enable easier scaling up of promising models within local markets and the transfer of best practices across markets in ways that can be sustained over the long term
- Gain insight into how and what students learn in real time by taking advantage of the greater variety, volume and velocity of data
- Increase teacher productivity, freeing up valuable time from tasks such as grading and testing, which can be used for differentiated teaching of competencies and character qualities

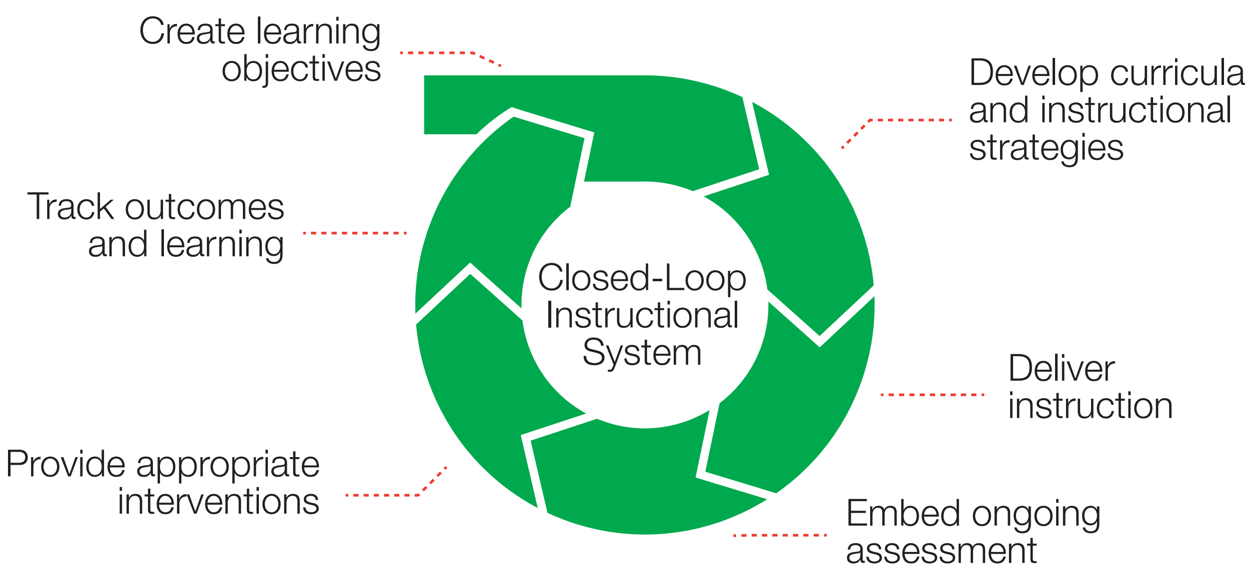
In addition, education technology can be deployed to develop 21st-century skills such as communication, creativity, persistence and collaboration, as is explored in the representative examples below.

Of course, technology is only one element in a portfolio of vital solutions that aim to close the 21st-century skills gap. These include strategies such as better teacher preparation, new modes of learning and wraparound services for struggling families.

But when educators add education technology to the mix of potential solutions, we find they are most effective if applied within an integrated instructional system known as the closed loop. As in engineering or manufacturing, the closed loop refers to a system that requires an integrated and connected set of steps to produce results. In the educational world, the closed-loop instructional system works similarly. At the classroom level of the closed loop, educators create learning objectives, develop curricula and instructional strategies, deliver instruction, embed ongoing assessments, provide appropriate interventions based on student needs and track outcomes and learning. All these efforts must be linked together as well as aligned with the goal of developing 21st-century skills *(see Exhibit 6)*.

To understand how technology can enhance learning as one tool in a portfolio, we surveyed the education technology landscape for trends and promising approaches to developing 21st-century skills. Based on our research and interviews with dozens of players in the education field, we homed in on a number of resources, as well as school networks that place a heavy emphasis on technology, as representative examples of those trends. In this section, we focus exclusively on skill development in primary and secondary education. By the time students enter college and the labour market, deficiencies that have not been addressed

Exhibit 6: An instructional system known as the closed loop is necessary to address skills gaps



earlier can be far more difficult and costly to remedy.

Through our analysis, we categorized the technologies that further strengthen the closed loop to address 21st-century skills gaps and deliver outcomes. The first category includes instructional resources that help address 21st-century skills gaps through the design, delivery and assessment of learning. These include personalized and adaptive content and curricula, open educational resources, communication and collaboration tools and interactive simulations and games. The second category includes institutional resources that help the closed loop deliver outcomes by improving human capital development and strengthening management systems. These include digital professional development resources for teachers and student information and learning management systems. At the end of this chapter, we also explore three school networks attempting to use education technology within the closed loop as they respond to the respective challenges found in different parts of the world.

When education technologies are layered throughout the closed loop, we argue that technology-based solutions such as the sample profiled here have the potential to enable teachers, schools, school networks and countries to scale up solutions in ways not possible before and potentially to deliver better outcomes and learning. That said, their inclusion in this report is not intended to serve as an endorsement: much more research must be done to identify the most effective uses of technology in the classroom and the most transferable solutions. In fact, most education technologies we surveyed come from the developed world and would require significant adaptations to respond to the unique challenges of and be successfully transferred to developing countries.

Instructional resources that enable the closed loop to address 21st-century skills gaps

Increasingly, best-in-class curricula aim to teach multiple skills at the same time. For example, teachers might use word problems to teach multiplication, directing students to think critically and solve problems while developing both literacy and numeracy skills. Education technology has the potential to become an option for teachers in delivering this combination of foundational literacies, competencies and character qualities.

At present, however, our research has found that most instructional activity in the education technology space has concentrated on the development of foundational literacies, given the focus of most educational standards around the world. While there has been some effort to develop competencies and character qualities, these skills are still not the primary focus of most educators and education technology developers *(see Exhibit 7)*. We conclude that to develop the full range of 21st-century skills, more resources need to be focused on competency and character quality development and aligned to particular skills. This, in turn, would help educators better evaluate products that best address their needs and contexts.

We further place the existing instructional resources into a few main categories. Those include: personalized and adaptive content and curricula, open educational resources, communication and collaboration tools and interactive simulations and games.

Personalized and adaptive content and curricula

Personalized and adaptive education technologies have mostly focused on developing foundational literacies. Product developers are attempting to deliver differentiated learning with one-on-one computer-based learning tailored to individual student needs, often used effectively with blended-learning approaches mixing in-person and online instruction. These programs can be used in conjunction with in-classroom instruction, freeing up teachers' time to deepen students' understanding of the material and to develop skills like problem-solving, creativity and collaboration. They can also harness the power of data to dynamically assess learning, address gaps and track outcomes.

Some longstanding programs, such as *Read 180*, first assess students' abilities, before later providing differentiated content based on a student's level. Others are more real-time and adaptive. The *Dreambox* mathematics application continuously analyses student actions to deliver millions of personalized learning paths tailored to each student's unique needs. Within one minute of work, the program can collect, analyse and respond to more than 800 pieces of data about a student and how he or she learns, according to the organization.

In addition to direct-to-student content, developers are also creating adaptive platforms. These can provide the back-end analytics necessary to offer an adaptive experience to students. For example, *Knewton* adaptively powers products from education companies ranging from start-ups to the largest publishers. Knewton provides an engine that allows others to build adaptive learning applications and experiences from a wide range of content, as well as to assess what works best. In addition, some companies are helping teachers create adaptive

Exhibit 7: Most educational technologies are focused on developing foundational literacies

	Personalized and adaptive content and curricula	Open educational resources	Communication and collaboration tools	Interactive simulations and games
Character Qualities	*Additional tools are strongly needed to develop competencies and character qualities*			• Games for Change
Competencies			• Google Apps for Education • OneNote • Facebook • Ponder	• Glass Lab • Games for Change • Molecular Workbench • Explore Learning • Tynker
Foundational Literacies	• Knewton • Dreambox • Read180 • Khan Academy • Smart Sparrow	• Betterlesson • LearnZillion • Curriki Geometry • netTrekker • Fishtree • Pearson • McGraw-Hill • Houghton Mifflin		• Explore Learning • Glass Lab • STMATH

Note: Illustrative sample of resources and tools featured.

learning experiences for students: *Smart Sparrow* provides a platform for teachers to create "adaptive pathways" for the lesson materials they create. This allows teachers to design a unique and differentiated experience for students.

For adaptive learning platforms to work well, subject matter is often broken down into discrete topics that enable a logical progression from one concept to another. Part of the reason we see adaptive learning focused primarily on literacy and numeracy is that these skills have already been broken down into chunks of concepts and their connections, which a computer can use to pinpoint how knowledge builds. Standardized reading levels have been developed, as well as "knowledge maps" for mathematics concepts, such as those used by personalized learning resource *Khan Academy*. As a result, we see personalized and adaptive technologies currently most used to strengthen the closed loop in developing foundational literacies.

To reach their full potential and further develop competencies and character qualities, these technologies need to take fuller advantage of the vast amount of data that is collected as students learn. They can use the data to better understand not just what students know, but also how they interact with content and learn best.

Open educational resources

Open educational resources (OER) increase the variety, accessibility and availability of content and curricula. Similar to personalized and adaptive tools, the focus of OER is primarily on foundational literacies. Digital platforms such as *LearnZillion*, *Curriki* and *BetterLesson* are free repositories of vast amounts of open-source content, which is often user-generated. These platforms allow teachers and schools to upload, share, edit and rate content online, creating a bank of both content (subject-knowledge materials) and curricula (such as lesson plans and pedagogical materials) created and vetted by teachers. For example, LearnZillion features more than 4,000 free open-source videos, Curriki offers more than 50,000 resources, ranging from individual lessons to complete courses and BetterLesson includes more than 10,000 Common Core-aligned lessons.

Well-established publishers such as *Pearson*, *McGraw-Hill* and *Houghton Mifflin* are also incorporating OER into their proprietary materials and platforms to allow teachers to customize their lessons. Other players such as *Fishtree* are designing similar content-creation platforms through which educators can customize their lesson plans, drawing from a wide range of resources.

Given the vast amount of free and open-source content available on the internet and the limited degree of quality control, there is a pressing need to differentiate content by quality, relevance and standards alignment. Without such quality control, it is challenging for teachers to identify and incorporate high-quality content into their teaching. However, some select examples are beginning to provide aggregated and curated digital content. Through crowdsourcing and expert reviews, *Curriki Geometry*

aggregates quality content and teaching materials from its platform into a comprehensive project-based geometry solution available for free. *netTrekker* contains a subscription-based repository of expert-reviewed, standards-aligned and carefully tagged content that makes it easier for teachers to find the resources they need.

Communication and collaboration tools

A number of tools are helping students develop competencies such as collaboration and communication by facilitating group work, peer-to-peer learning and peer feedback. These tools can be further enhanced by project-based and experiential-learning pedagogical approaches that help students work together to solve problems in real time.

Students can collaborate in real time on assignments using digital tools such as *Google Apps for Education* to collectively develop documents, spreadsheets and presentations. Online communication tools also allow students to help each other. Students can now create and share digital notebooks through tools such as *OneNote*; discuss readings and assignments, share related information and keep up with classroom announcements through social networking sites such as *Facebook*; and comment on and discuss assigned readings through such sites as *Ponder*.

Interactive simulations and games

Games and simulations allow students to go beyond the traditional lecture and to interact with instructional content in an engaging way that has been called "gameful learning". Most of the activity in this corner of the education technology space is happening within numeracy and scientific literacy. Even so, games allow a focus on multiple skills at once: while students work to improve their understanding of core concepts, they can also develop skills such as creativity, curiosity and persistence in the process. These tools, along with new pedagogical approaches such as project-based learning, are therefore at the forefront of addressing skills gaps in competencies and character qualities.

Game-based programmes such as *STMath* use non-numerical visualizations to develop students' intuitive understanding of mathematical concepts before attaching the symbols of traditional mathematics instruction. Instructional simulations, such as those from *ExploreLearning* and *MolecularWorkbench*, allow students to interact with abstract scientific concepts in ways that would be costly or impossible to replicate in the classroom.

Some developers are providing students with opportunities for indirect competency development through challenging experiences that require more advanced reasoning from students. For example, *GlassLab* has adapted the popular *SimCity* computer game to education, with robust assessments from ETS and Pearson and grant funding from the Gates and MacArthur foundations. *SimCityEDU: Pollution Challenge!* has four missions, each with distinct focuses on developing standards-aligned skills such as systems and critical thinking and cause and effect.

Competencies are also being indirectly developed though platforms such as *Tynker*. The site's interactive online learning games are used by more than 10,000 primary and secondary schools to teach basic computer programming skills and show potential to foster not just technological literacy but also competencies such as problem-solving, creativity, collaboration and persistence.

Few tech-based tools have been created that focus exclusively on character qualities development. This highlights the lack of attention that traditional education has given to these skills, as well as the opportunity available to product developers. An interesting exception is *Games for Change*, an organization that curates and incubates games focusing on social issues. Games have been developed that build social and cultural awareness in a variety of topics, including economics, the environment, civics and conflict. For example, *Mission US: A Cheyenne Odyssey* tells the story of westward expansion in the United States through the eyes of Native Americans.

Institutional resources that enable the closed loop to deliver outcomes

Two important sets of resources work to strengthen the closed loop at the institutional level, be it the school, network or district. Those improvements develop a key resource – teachers – as well as create better systems and data flows.

By broadly strengthening human capital and technology infrastructure – two critical elements often challenged in many educational systems – each set of resources allows for greater productivity, efficiency and effectiveness at all levels of the closed loop.

While we highlight a number of innovative examples, we observe that most digital professional development resources for teachers disproportionally focus on helping them improve foundational literacies in their students, without adequate attention to developing competencies and character qualities. To help address skills gaps, teacher training should be better aligned to 21st-century skills. In addition, administrators need to improve the use of data in learning and decision-making at both the school and system levels.

Digital professional development resources for teachers

For countries to succeed at generating 21st-century skills, they also need to help teachers more efficiently and productively develop their own skills.

Emerging online resources in professional development for teachers can have a positive impact, adding more instructional strategies to a teacher's repertoire, as well as improving their ability to execute on these strategies in the classroom. Instead of attending a district-mandated workshop with a group of other teachers at a specific date and time, now teachers can also access materials that are targeted to their particular needs anytime and anywhere.

Platforms such as *TeachScape* and *KDS* are personalizing development by providing relevant digital courses to teachers. TeachScape features more than 160 digital courses and more than 2,500 high-quality videos of teaching practice, for example. Thanks to digital resources such as these, it is easier than ever before for teachers to get the help they need to improve their instructional skills.

Technology is also fostering collaboration and coaching among teachers through tools such as video feedback and remote coaching. *Edthena*, for example, allows teachers to upload their video-recorded lectures so that other teachers and mentors on the platform can give direct feedback about the strengths and weaknesses of their teaching. Another platform, *Edconnective*, allows teachers to connect remotely with experienced teachers who can coach them during one-on-one digital sessions targeted to their specific needs.

Across the teacher professional development space, another nascent trend involves developing digital courses specifically targeting competencies and character qualities. For example, *KDS* has a course, "21st-Century Skills", in which teachers learn about new educational methods to teach

higher-order skills. Traditional hardware-oriented technology players have also moved into the professional development space. In addition to providing face-to-face learning, they have developed blended-education approaches featuring online courses, materials and teacher communities such as *Intel Teach* and *Microsoft Partners in Learning* that governments, school leaders and teachers are using to develop 21st-century skills.

Student information and learning management systems

Technology is allowing student data to be generated from an increasing number of sources, ranging from more traditional student information systems (SISs), which collect enrollment, course history and achievement data, to classroom lessons, activities and digital instructional content platforms, which are frequently channelled through learning management systems (LMSs). In addition to collecting data, LMSs have tremendous potential to indirectly facilitate the development of 21st-century skills such as collaboration and communication as students interact with digital content and with each other.

Student information and learning management systems often operate in a vacuum, however, with too little sharing and interpretation of data to help educators and administrators make informed, data-driven decisions. One US Department of Education study found that only half of teachers could accurately interpret data from their systems, for example.[7]

Greater interoperability between LMSs and SISs would allow educators to have a more comprehensive view of student learning and performance. As systems such as these become more integrated and better able to continuously track data at a detailed level over time, they can offer educators and policy-makers a better understanding of student achievement in the context of teacher performance, course design and other areas.

Major players are starting to develop more integrated solutions, such as Pearson's *Schoolnet for PowerSchool*, which combines assessment and reporting data into its widely used web-based SIS. Some charter schools are building interoperable systems as well, including *Summit Public School's* partnership with *Illuminate* to combine an SIS with assessment and reporting data. Other examples, such as *Edmodo*, *Schoology* and *Canvas*, include customizable LMS platforms that aggregate a variety of content resources.

[7] Rankin, Jenny. "When Data Systems Actively Support Data Analysis." EdSurge. June 28, 2014. (https://www.edsurge.com/n/2014-06-28-when-data-systems-actively-support-data-analysis/)

Building the closed loop on the ground

A great deal of activity is happening within school systems to use technology to address unique challenges at the local level. A few networks of schools demonstrate how technology can be used to develop 21st-century skills – where technology is needed most and where it focuses on different levels of the closed loop. The best examples of this work often reinforce pedagogical approaches such as experiential, project-based, inquiry-based and adaptive learning, which are critical to the teaching of 21st-century skills.

Three school networks illustrate the use of technology in different country contexts – *Bridge International Academies* in Kenya (a low-income country), *Innova Schools* in Peru (an upper-middle income country) and *Summit Public Schools* in the United States (a high-income OECD country). Each example exists along a continuum of technology deployment, ranging from more focused to more holistic. And each one prioritizes technology across the closed loop according to the respective challenges faced within a country. For instance, policy-makers might prioritize the use of education technology to provide country-specific solutions, such as by addressing a lack of technology infrastructure, while educators might use education technology to prioritize changes at the classroom and network level, such as by addressing teacher absenteeism. At the same time, these best practices have the potential to be transferred to environments that face similar challenges, including poor infrastructure, weak human capital development or low college-completion rates.

By highlighting these diverse school networks, our goal is not to evaluate their approaches, outcomes or impact. Our intention is simply to present the variety of ways technology solutions are being implemented given local challenges holding back the development of 21st-century skills. The school networks featured represent emerging examples of technology's potential to find creative solutions to unique challenges at the local level, although these organizations' insights have yet to work their way into the mainstream or reach notable scale. Nonetheless, these projects hint at the direction in which the education technology space may be moving and could offer powerful lessons to educators, policy-makers and the business community alike.

Bridge International Academies

Kenya faces a number of serious educational challenges related to human capital. For example, 42% of all instructional time is lost due to teacher absenteeism from the classroom.[8] In addition, only 35% of Kenya's public school teachers display mastery in the subjects they teach.[9] As a reflection of these and other challenges, Kenyan students struggle to acquire even the most fundamental skills of literacy and numeracy: Kenya ranks in the 21st percentile for literacy and numeracy out of the 91 countries we studied.

Working within this resource-constrained context is *Bridge International Academies*, a private-school network of 405 schools spread across nearly every county in Kenya, with more than 120,000 children currently enrolled in its iconic lime-green-roofed academies. *Bridge* is using education technology in a highly focused way, primarily on one high-priority element of the closed loop – instructional delivery – to address foundational skills *(see Exhibit 8)*. Given its context working in a low-income country significantly lacking in resources and infrastructure, *Bridge* uses a relatively low-tech approach, focusing the use of education technology on teachers, a critical educational resource. Its model, which separates content development from instructional delivery, is proving transferable to other similar low-resource environments facing human capital constraints.

Bridge employs master teachers to develop curricula centrally, in the form of scripted lesson plans for 40-minute lessons that are used in every classroom across the network. Individual teachers receive these scripted lessons electronically via a tablet, along with more than 300 hours of initial induction training and in-service professional development from coaches who visit schools every three weeks. Teachers hold the tablet while delivering the content, following detailed instructions specifying everything from instructional content to classroom activities. Through its scripted instructional delivery approach, *Bridge* provides a standardized learning experience across its network, helping to control for the high variability in teacher quality across the country. In addition, its approach of separating content development from delivery allows teachers to focus on teaching children instead of creating their own lesson plans, a task that can be particularly challenging when teachers haven't mastered the curricula they teach. (Students learn with the help of traditional textbooks, workbooks, slates and other inexpensive tools.)

Technology also helps *Bridge* track teacher absenteeism rates and performance using its tablets, increasing teacher accountability – a key challenge in Kenya. To receive the centrally created curricula and lesson plans for the day, *Bridge* teachers must log on to their tablet when the day begins. This allows *Bridge* to see when teachers have arrived. Absences trigger automatic communications and follow-up actions, including calling in substitute teachers to cover classes. Through this tracking and reminder system, *Bridge* has been able to achieve teacher absenteeism rates of less than 0.5% in its schools, according to the organization. Teachers also connect their tablets to *Bridge's* servers at the end of the day, sending data that includes teacher and student attendance, assessment scores, the start and ending time of every lesson and pages taught during lessons.

In a more limited way, *Bridge* also uses education technology in the closed loop to assess students, provide timely interventions and track student outcomes. Teachers manually input student performance data into *Bridge's* tablet-based digital tracking system. Through this system, *Bridge* is able to follow up with interventions targeted to underperforming schools, as well as to modify curricula based on the most effective strategies for improving student outcomes. Student assessment data is also used to facilitate small-group and one-on-one tutoring.

As a result of its efforts to standardize teaching and learning, *Bridge* estimates that its students have gained almost an extra year of reading and mathematics instruction compared with neighbouring public schools.[10] In the process, *Bridge* offers an education at a relatively low price compared to similar schools. Attending a *Bridge* school costs an average of $7 per month, affordable enough for most of its low-income families, who earn an average of $136 per month, according to the organization.

In addition to adopting education technology in teaching and learning, *Bridge* also uses centralized technology platforms and systems that enable it to rapidly scale up its school model. The organization deploys standardized curricula, real estate, legal, human resources, production, marketing and other approaches across its network from the central office. For example, its research department pinpoints the best locations for a new academy to be built based on the needs and incomes of local families, using mobile surveys, GPS data from on-the-ground surveyors and satellite imagery.

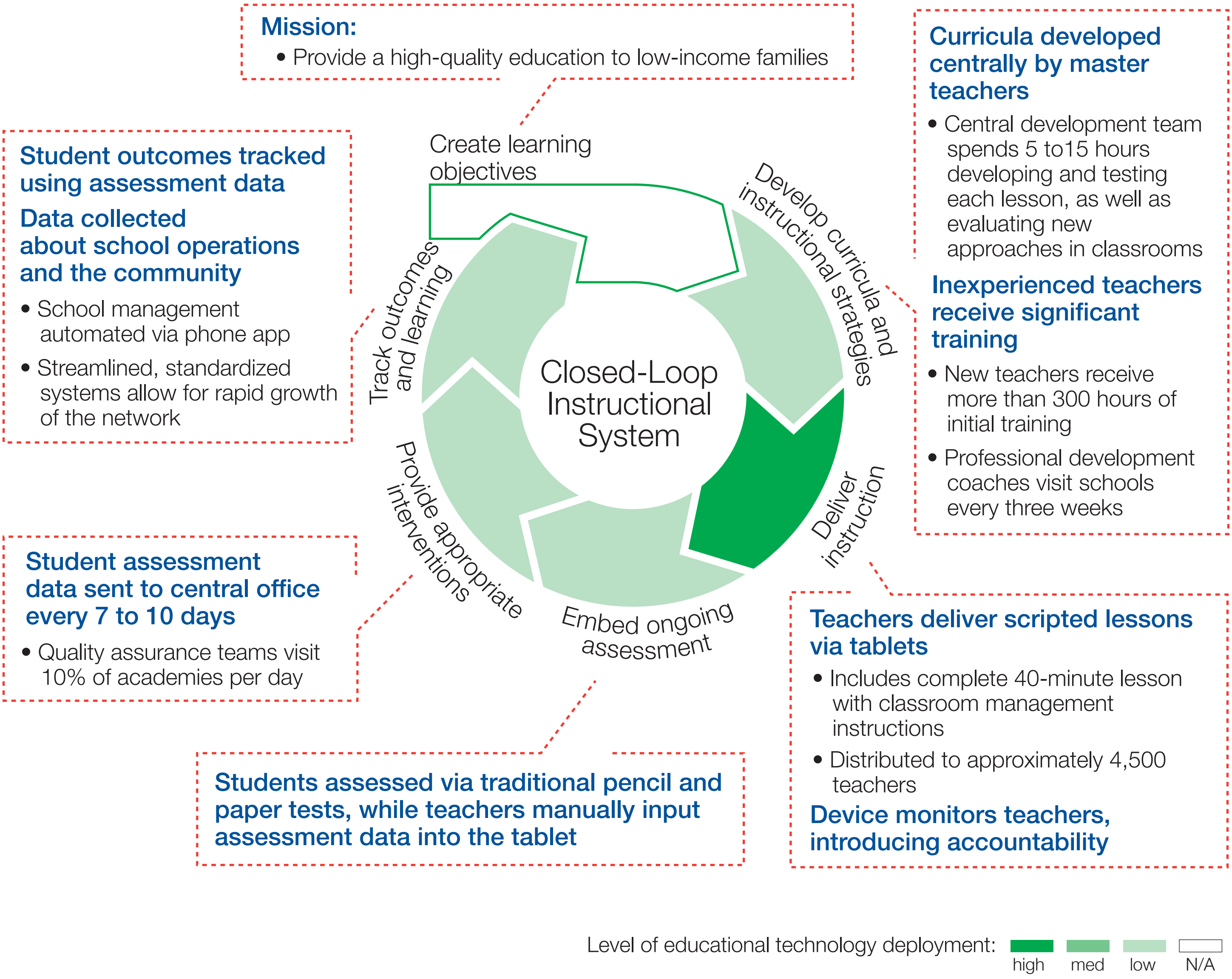
Bridge's focus on centralized systems, research and data collection and continuous feedback has allowed the network to launch a new school approximately every three days. The organization has set itself an ambitious goal of educating 10 million low-income students in a dozen countries within 10 years.

[8] Martin, Gayle H. and Obert Pimhidzai. "Education and Health Services in Kenya: Data for Results and Accountability." Service Delivery Indicators Initiative. World Bank, African Economic Research Consortium and African Development Bank. 2013. (http://www-wds.worldbank.org/external/default/WDSContentServer/WDSP/IB/2013/07/25/000442464_20130725101359/Rendered/PDF/794420REVISED00untryReport0wAuthors.pdf)

[9] Ibid.

[10] "The Bridge Effect: Comparison of Bridge Pupils to Peers at Nearby Schools EGRA-EGMA Evaluation Programme." Bridge International Academies. Fall 2013 results, with a July 2011 baseline. (http://www.bridgeinternationalacademies.com/wp-content/uploads/2013/01/Bridge-International-Academies_White-Paper_The-Bridge-Effect_Nov-2014_Website.pdf)

Exhibit 8: How *Bridge International Academies* uses education technology across the closed loop



Innova Schools

Peru also faces significant human capital challenges. Teachers have limited proficiency in even foundational literacies. According to 2007 census data, 62% of teachers did not reach an acceptable level on sixth grade reading tests and 92% did not reach an acceptable level for sixth grade mathematics.[11] These limitations in teaching ability and other factors are reflected in student performance: in 2013, only 17% of nationally assessed students were proficient in mathematics and 33% were proficient in literacy.[12]

Consider how *Innova Schools* is tackling these and other obstacles in a lower-middle-income environment. The low-cost private-school network aims to provide a world-class education to the growing Peruvian lower-middle class. It currently serves more than 13,000 students in 23 schools, with a target of 75,000 students in 70 schools by 2021. To do this, *Innova's* use of technology focuses not just on teachers, but also on students, with the greatest integration within instructional delivery, support for its inquiry-based pedagogy and assessment *(see Exhibit 9)*. Its model could be transferable to other environments facing a mix of challenges involving human capital development and other factors.

Innova uses a two-pronged, teacher-focused approach to combat the nation's human capital problems in education. Like *Bridge*, the network also develops its curriculum centrally. To date, it has created more than 20,000 scripted lessons for teachers, accessible through its Teacher Resource Center, a repository of teacher resources designed by a group of in-house specialists. *Innova* has also developed a holistic professional development strategy, investing heavily in teacher training and coaching. Teachers receive more than 100 hours of

[11] "An Alternative Reading of the IADB Study on Peru's OLPC Implementation." One Laptop Per Child. 2012. (http://www.olpcnews.com/countries/peru/an_alternative_reading_of_the_iadb_study_on_peru_olpc_implementation.html#sthash.h9KhBe44.dpuf)
[12] Census Evaluation of Students (Sistema de Consulta de Resultados de la Evaluación Censal de Estudiantes, ECE (SICRECE). Innova Schools data. 2013. (http://sistemas02.minedu.gob.pe/consulta_ece/publico/index.php)

Exhibit 9: How *Innova Schools* uses education technology across the closed loop

Mission:
To provide high-quality education to the emerging Peruvian middle class

- Blended learning, student-centred pedagogy and inquiry and whole-child development are at the centre of the educational model

Technology-enabled platforms used to measure performance on an ongoing basis:

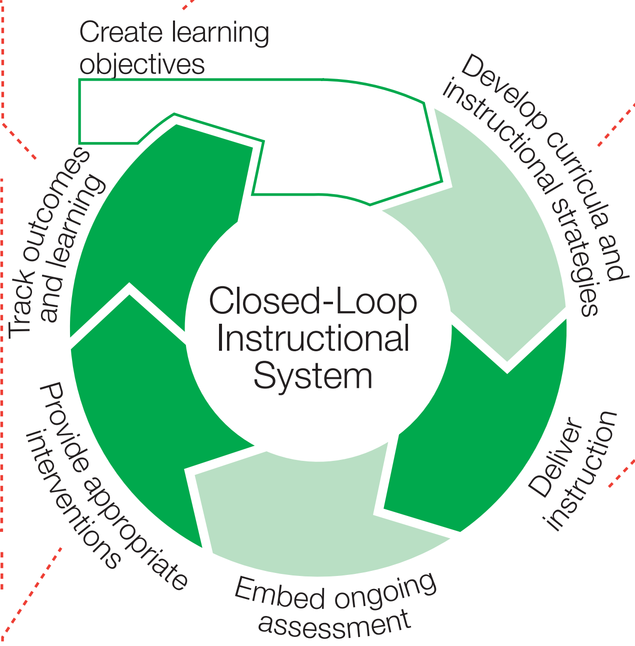
- PowerSchool software used to record student grades and track progress
- Teacher Observation Platform used to track teacher performance

Effectiveness framework used to evaluate network quarterly

- Standards of excellence defined for the entire system

Computer-based instruction identifies learning gaps as they emerge, allowing for immediate interventions

- For example, *Khan Academy* provides customized assessments



In-house development of content according to learning standards

- 20,000+ scripted lessons

High level of investment in human capital

- Developed teacher "university", with training for multiple levels along the career path

Blended learning approach to instruction

- 30% self-directed, computer-based learning
- 70% teacher-led, inquiry-based instruction, with "flipped" classrooms piloted in two schools

Internal quality-assurance department analyses student data

- Annual analysis of performance data about reading and mathematics
- Separate assessment tools for higher-order skills, such as leadership, teamwork and global citizenship
- Network-wide standardized tests in core skills

Level of educational technology deployment: high med low N/A

training per year through a corporate university and partnerships with leading institutions, as well as support through career development and mentorship programmes. Instructional coaches observe and give teachers feedback, record data from teacher observations on its online Teacher Observation Platform and identify teachers who may be struggling and need additional support. To ensure success with its innovations, *Innova* principals act as instructional leaders within the school: they make learning a priority at all school levels, use professional learning communities to build teacher capacity and rely on data analysis to track progress and direct actions.

Although professional development elements such as these are not strongly reliant on technology, they provide the foundation on which *Innova* has successfully deployed technology throughout the closed-loop system. Building on that base, *Innova* focuses on providing a deep integration of educational technology into the instructional delivery element of the closed loop. The school uses a blended learning approach in which students spend 30% of class time on computer-based learning ("solo time") and 70% on teacher-led collaborative learning sessions ("group time"). During computer-based solo time, students learn at their own pace through Khan Academy for mathematics, MyEnglishLab for English-language reading and writing, Leo for Spanish and Modus for science. Once students have acquired basic knowledge on a topic, teachers can focus group time on applying new content to different situations, working on more complex problems, thinking critically and helping students collaborate and communicate with one another.

Computer-based learning platforms also allow *Innova* to assess students in real time, provide timely interventions and track student outcomes. Each of the technology products *Innova* uses has a dashboard feature that highlights areas of difficulty for individual students. Students may use virtual tools outside of the school day for additional practice on concepts they may be struggling with. In addition, teachers review assessment data at the end of each quarter to identify areas for improvement and to plan for the quarter ahead.

Education technology serves to complement *Innova's* pedagogical approach of inquiry-based learning during group time. Classes start with a set of questions that challenge students, use their prior knowledge and engage them in the learning process. Once students explore the answers to those questions, teachers help them build new knowledge through short concept overviews and more challenging questions which they resolve collaboratively.

In part as a result of these elements of the closed loop, 61% of *Innova* students tested proficient in mathematics and 83% in literacy, up to three times higher than the national average. In addition, 86% of *Innova* students attend university or a technical college, according to the organization.

Innova is testing and learning from its efforts to improve these results further. It is currently piloting a "flipped classroom" instructional model that relies on digital content students can access at home to improve foundational literacies, while maximizing classroom time to collaborate with teachers and other students as they extend their skills and develop competencies and character qualities.

Summit Public Schools

While the United States ranks in the middle of OECD countries on many 21st-century skills, significant differences remain between high-income and low-income students in the country's public schools. For instance, only 30% of low-income students enroll in college, compared with 80% of high-income students.[13] And low-income students drop out of college at almost three times the rate of those with high-incomes.[14]

Summit Public Schools, a network of nine charter schools based in the San Francisco Bay Area and Washington State serving a diverse student body of nearly 2,000 students, seeks to address these challenges with a mission of preparing students for success in college, career and life. *Summit* holistically deploys education technology across the closed loop, with a focus on teachers and students and uses education technology to strengthen its project- and competency-based learning approach *(see Exhibit 10)*. Its model could be transferable to other developed-country environments with similar challenges that also feature a high degree of teacher autonomy.

Starting with learning objectives, *Summit* has developed a shared skill rubric that incorporates 36 skills targeted at college readiness, including competencies such as critical thinking. *Summit* believes that all students should be prepared with the foundational literacies, higher-order competencies and character qualities needed to be successful in college.

In terms of curricula and instruction, *Summit* students spend the majority of their time on project-based learning and teacher-led sessions. For the remainder of the day, students work through assignments at their own pace. The self-directed component enables *Summit* students to take responsibility for their own learning and to strengthen character qualities such as persistence, initiative, curiosity and adaptability, while the group component fosters further development of competencies through discussion, critical thinking and collaboration.

Summit's curricula features more than 200 activities that focus on developing skills such as problem-solving and communication, according to the organization. Project-based activities are mapped to a cognitive-skills rubric that is shared across all subject areas and grade levels. *Summit* assesses students on their development of cognitive skills through other activities, based on the rubric. Students submit all assignments using Google Docs to give feedback to each other and receive feedback from their teachers.

Summit's content curricula relies on in-house designed "digital playlists" for online, self-directed learning. Playlists include multiple types of internally and externally developed content, such as exercises, videos and quizzes, mapped to specific skills within its learning rubric. Students advance

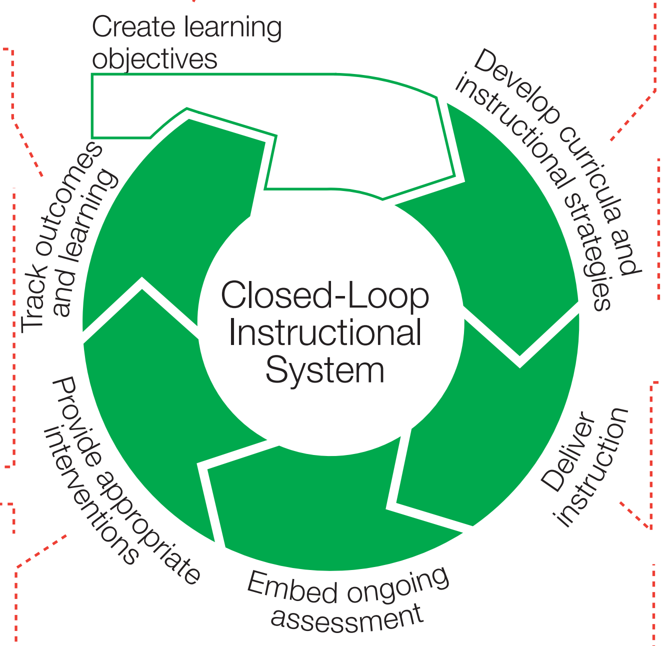
[13] Bailey, Martha J. and Susan M. Dynarski. "Gains and Gaps: Changing Inequality in US College Entry and Completion." NBER Working Paper No. 17633. December 2011. (http://www.nber.org/papers/w17633) See also: http://www.mnprivatecolleges.org/sites/default/files/downloads/news/college_by_income.pdf.

[14] "Six-Year Degree Attainment Rates for Students Initially Enrolled in Four-Year Institutions." Pell Institute. December 2011. (http://www.pellinstitute.org/fact_sheets.shtml)

Exhibit 10: How *Summit Public Schools* uses education technology across the closed loop

Mission:
To prepare students for success in four-year colleges
- Emphasis on student ownership of learning

Personalized Learning Plan (PLP) integrated across the learning experience
- Students check PLP progress daily; plan shows performance relative to a student's personal college goal
- Teachers use student data to adjust current and future projects



Customized project-based learning approach
- *Summit* teachers develop learning projects, assessing cognitive skill development via subject-specific content
- "Playlists" of digital resources are aligned to each project

Blended learning for mathematics and reading
- Higher performing students use individualized, computer-based instruction such as Khan Academy and Curriculet
- Lower performing students receive small-group, teacher-led instruction

Teacher-led, project-based instruction

Self-directed personalized learning time on laptops

Computer-based instruction allows for targeted interventions
- Teachers focus on areas with greatest need
- Additional remediation available through playlists

One-on-one teacher mentorship meetings weekly

Online assessment platform integrated with PLPs and academic playlists
- Pre- and post-assessments coupled with playlists
- Data on skill mastery fed into PLP

Level of educational technology deployment: high med low N/A

through these playlists at their own pace, taking assessments as they feel ready. In addition to the playlists, students work on platforms such as Khan Academy to improve foundational literacies.

Thanks to specially designed performance tracking software known as a personalized learning plan (PLP), students evaluate their learning in real time and help set their learning goals for the week, month, semester and year with the help of a mentor with whom students meet weekly. In terms of assessment and progress tracking, *Summit* takes a unique approach: teachers work as coaches to help students interpret their successes and failures, learn how to set new plans and goals and push their skill development.

The PLP, assessments and measurements of skill growth are viewable by other grade-level teachers and administrators, which helps teachers and school leaders devise appropriate interventions to improve student outcomes. Parents can also log into the PLP to see a student's progress.

Students typically arrive at *Summit* schools with slightly lower scores than students at local high schools, yet outperform their peers during their time at its charter schools, according to the organization. *Summit* schools have consistently performed above California's measure of a successful school, with an average score of 826 on the state's Academic Performance Index (successful schools are defined as those scoring 800 or greater on the API test). Thanks to its college-prep-focused curricula in which every student takes six AP courses, 96% of *Summit* students are accepted to at least one four-year college or university. They complete college within six years at double the national average.

Chapter 4: System-wide priorities for stakeholders

Students require new skills in the 21st century, while educators and other stakeholders require new measures of performance. Education technology has the potential to fundamentally increase efficiency and effectiveness throughout the closed loop, as well as a unique potential to facilitate the teaching of 21st-century skills beyond foundational literacies.

However, in most places, education technology has been deployed only recently, with outcomes highly dependent on how well technology can be integrated holistically to address an individual country's context. In the most developed countries, the primary focus should be on scaling successful approaches, while expanding technology's ability to address new skill needs such as competencies and character qualities. In the least developed countries, the development of foundational literacies is often a much more pressing problem. The main focus in many of these countries should be on adapting and experimenting with some of these promising, albeit early-stage technological solutions from the developed world.

To understand how stakeholders can move forward in many of these directions at once, it's helpful to come back to our closed-loop model. In addition to operating at the level of the classroom and the school network, the closed loop also operates systemically – whether at the country, state or the district level. For example, at the country level, policy-makers can help define the learning objectives and policies tied to the overall aspirations for a knowledgeable and economically productive citizenry. Educators then design the standards and specific curriculum, deliver selected models and assess their efficacy.

Policy-makers and educators have a particularly useful role to play at the system level in embedding 21st-century skills and education technology across the closed loop. But fulfilling the promise of the closed loop will require a multistakeholder approach involving not just policy-makers and educators, but also educational-technology providers and funds. These stakeholders can take a number of actions.

Stakeholder group	Primary role	Actions/capabilities needed
Policy-makers	• Assess and realign educational systems and standards for the development of 21st-century skills	• Agree on definitions and globally uniform standards to measure 21st-century skills • Incorporate all 21st-century skills into learning standards, including competencies and character qualities • Certify new instructional content such as OER and align it to 21st-century skills standards • Direct assessment towards 21st-century skills, incorporating new metrics beyond foundational literacies
	• Identify and prioritize key skills gaps, paying attention to the needs of local economies, available resources, and unique country-level constraints	• Track performance in relation to peers and over time • Prioritize gaps, set clear targets and develop action plans to address gaps and overcome country-level constraints • Work in collaboration with the private sector to improve skills critical to the workforce of the future • Create incentives for education technology providers to develop products and services that develop competencies and character qualities
	• Create a learning environment that supports innovation, both from schools and from education-technology players	• Give schools the autonomy to innovate while maintaining accountability for high learning standards • Provide funding for innovative school networks that demonstrate improved outcomes • Create a dialogue with innovative players to accelerate the spread of best practices into the mainstream

Stakeholder group	Primary role	Actions/capabilities needed
Educators (such as teachers, school principals and local and regional administrators)	• Scale up, transfer and promote the most successful models	• Scale up effective new models within countries by identifying core elements of success, securing stable funding sources, and creating a dialogue with policy-makers to ensure a continuous integration of innovative approaches into the mainstream • Promote and transfer effective models in new markets by standardizing key instructional and operational model elements, adapting to local needs, and using data to continuously track and compare both output and outcome metrics
	• Evaluate whether education technologies can be adopted throughout the closed loop, given unique country contexts	• Develop and promote understanding of and expertise in technology • Focus investment on the technology infrastructure with the strongest potential, such as the hardware necessary for blended instruction, effective computer-based learning programmes, and integrated assessment and data platforms • Ensure interoperability between instructional strategies, assessment systems and learning platforms to enhance decision-making related to students, teachers and administrators
	• Develop and promote technology expertise among teachers	• Incorporate 21st-century skills proficiency into teacher qualification and professional development • Provide teachers with ongoing support to effectively integrate technology solutions into the classroom
Education technology providers	• Develop products to fill gaps in 21st-century skills measurement and instruction	• Develop tools and business models that are financially viable in the developing world, that address its unique environment and constraints, and that work to overcome the digital divide • Build tools that go beyond foundational literacies and specifically target competencies and character qualities • Support the development of comprehensive global assessments and measurements for 21st-century skills
	• Help shape the public education agenda	• Engage in the public debate about education and promote the need for the development of skills most demanded in the job market • Promote the scaling up of proven innovations through partnerships, dialogue and advocacy
Funds and alliances	• Accelerate the development and implementation of global measures of 21st-century skills	• Support metrics development and greater integration of measurements for both 21st-century skills and factors that constrain their development • Help increase coverage and comparable performance data collection in developing countries • Provide the funding needed to research and develop metrics necessary to identify effective technology-based solutions at an early stage
	• Provide funding to pilot, transfer and scale up technology-enabled models	• Accelerate the migration of technology-driven models from developed to developing markets, once key instructional and operating features have been standardized and models have been adapted to local needs • Focus seed funding on solutions with both a high impact on outcomes and sustainable financial models • Invest in innovation incubators for education technologies in the developing world • Provide resources and advice to pilot technology-enabled models for the development of competencies and character qualities

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Appendix 1: Definitions of 21st-century skills

Category	Skill	Definition
Foundational literacies	**Literacy**	Ability to read, understand and use written language
Foundational literacies	**Numeracy**	Ability to use numbers and other symbols to understand and express quantitative relationships
Foundational literacies	**Scientific literacy**	Ability to use scientific knowledge and principles to understand one's environment and test hypotheses
Foundational literacies	**ICT literacy**	Ability to use and create technology-based content, including finding and sharing information, answering questions, interacting with other people and computer programming
Foundational literacies	**Financial literacy**	Ability to understand and apply conceptual and numerical aspects of finance in practice
Foundational literacies	**Cultural and civic literacy**	Ability to understand, appreciate, analyse and apply knowledge of the humanities
Competencies	**Critical thinking/ problem-solving**	Ability to identify, analyse and evaluate situations, ideas and information to formulate responses and solutions
Competencies	**Creativity**	Ability to imagine and devise new, innovative ways of addressing problems, answering questions or expressing meaning through the application, synthesis or repurposing of knowledge
Competencies	**Communication**	Ability to listen to, understand, convey and contextualize information through verbal, nonverbal, visual and written means
Competencies	**Collaboration**	Ability to work in a team towards a common goal, including the ability to prevent and manage conflict
Character qualities	**Curiosity**	Ability and desire to ask questions and to demonstrate open-mindedness and inquisitiveness
Character qualities	**Initiative**	Ability and desire to proactively undertake a new task or goal
Character qualities	**Persistence/ grit**	Ability to sustain interest and effort and to persevere to accomplish a task or goal
Character qualities	**Adaptability**	Ability to change plans, methods, opinions or goals in light of new information
Character qualities	**Leadership**	Ability to effectively direct, guide and inspire others to accomplish a common goal
Character qualities	**Social and cultural awareness**	Ability to interact with other people in a socially, culturally and ethically appropriate way

Sources: ESCO Skills Hierarchy for Transversal Skills (https://ec.europa.eu/esco/web/guest/hierarchybrowser/-/browser/Skill); Partnership for 21st Century Skills. "Framework for 21st Century Learning." NEXT: Washington DC, 2001; Burkhardt, Gina. "enGauge 21st Century Skills: Literacy in the Digital Age." North Central Regional Educational Laboratory and The Metiri Group, 2003. (www.ncrel.org/engauge); Learning Metrics Taskforce. "Towards Universal Learning: What Every Child Should Learn." Center for Universal Education at the Brookings Institution and UNESCO Institute for Statistics: Washington, DC, 2013; The Economist Intelligence Unit. "The Learning Curve: Education and Skills for Life." Pearson: London, 2014. Other sources considered but not included: AT21CS, WorldSkills, Iowa Dept. of Education's 21st Century Skills, and Tony Wagner's Seven Survival Skills.

Appendix 2: The measurement challenge

Measuring 21st-century skills presents numerous obstacles. Researchers have access to only limited direct metrics to assess performance on the full range of skills. In addition, the coverage of these metrics is often confined to the developed world.

The majority of tests measuring 21st-century skills focus on foundational literacies. Beyond the indicators we used in our methodology – the Programme for International Student Assessment (PISA), the Southern and Eastern Africa Consortium for Monitoring Educational Quality (SACMEQ) and the Latin American Laboratory for Assessment of the Quality of Education (LLECE) – other tests that measure literacy, numeracy and scientific literacy include the Progress in International Reading Literacy Study (PIRLS), the Early Grade Reading Assessment (EGRA), the Program for the Analysis of Education Systems (PASEC) and the Trends in International Mathematics and Science Study (TIMSS).

The three other literacies – financial, ICT and cultural and civic – have not been part of the traditional focus of international assessments and therefore there is less data and fewer assessments available to draw on. The only test currently available for financial literacy is PISA, but that test covers only 16 countries. For civic and cultural literacy, we evaluated two direct measurements, the International Civic and Citizenship Education Study (ICCS) and the Civic Education Study (CivEd). We picked ICCS for its wider coverage. Finally, we used PISA's digital literacy assessment, which is a valuable assessment but has limited global coverage.

We found large gaps in coverage in the measurement of many core skills. When we combined existing metrics for literacy and numeracy, for example, we were able to cover fewer than half of the countries in the world.

Measurement challenges are amplified when it comes to competencies and character qualities. PISA has pioneered the assessment of problem-solving, a key competency. This assessment still covers only approximately 44 countries. For creativity, communication and collaboration, no direct measurements exist to date. For creativity, we used a proxy from one of the sub-scores in PISA's mathematics assessment.[15] We encountered difficulties finding metrics that measure character qualities, with the exception of curiosity. For that metric, we used PISA's problem-solving subscale.[16]

Note that PISA is in the middle of promising work to extend its 2015 and 2018 assessments. It plans to add collaborative problem-solving and global competencies, measuring skills such as intercultural understanding, empathy and perspective taking.

It is critical that countries support and facilitate research to improve both the direct measurement of 21st-century skills as well as their global coverage. Only then will countries be able to create an accurate baseline from which to measure progress in the future.

[15] PISA 2012 mathematics subscale: "For individuals to use their mathematical knowledge and skills to solve a problem, they often first need to translate the problem into a form that is amenable to mathematical treatment. The framework refers to this process as one of formulating situations mathematically. In the PISA assessment, students may need to recognize or introduce simplifying assumptions that would help make the given mathematics item amenable to analysis. They have to identify which aspects of the problem are relevant to the solution and which might safely be ignored. They must recognize words, images, relationships or other features of the problem that can be given a mathematical form; and they need to express the relevant information in an appropriate way, for example in the form of a numeric calculation or as an algebraic expression."

[16] PISA 2012 Creative Problem Solving, acquisition of knowledge subscale: "In knowledge-acquisition tasks, the goal is for students to develop or refine their mental representation of the problem space. Students need to generate and manipulate the information in a mental representation. The movement is from concrete to abstract, from information to knowledge. In the context of the PISA assessment of problem solving, knowledge-acquisition tasks may be classified either as "exploring and understanding" tasks or as "representing and formulating" tasks."

Appendix 3: Indicators considered and used in the report

Indicators considered and used to estimate skills gaps:

	Skill	Indicator	Source
Foundational literacies	**Literacy**	• **Mean PISA 2012, 2009 reading score** • **Mean SACMEQ III reading score** • **Mean LLECE reading score** • Mean PIRLS literacy score • Mean EGRA score • Mean PASEC reading score • Youth literacy rate	• **OECD** • **UNESCO (IIEP)** • **UNESCO** • IEA • USAID (funded) • UNESCO (IIEP) • UNESCO
	Numeracy	• **Mean PISA 2012, 2009 mathematics score** • **Mean SACMEQ III mathematics score** • **Mean LLECE mathematics score** • Mean TIMSS mathematics score • Mean EGMA score • Mean PASEC mathematics score • Quality of science and mathematics education index	• **OECD** • **UNESCO** • **UNESCO** • IEA • USAID (funded) • UNESCO (IIEP) • WEF
	Scientific literacy	• **Mean PISA 2012, 2009 science score** • **Mean LLECE science score** • Mean TIMSS science score • Quality of science and mathematics education index	• **OECD** • **IEA** • UNESCO • WEF
	ICT literacy	• **PISA 2012 Digital Reading Assessment** • Students per computer in school • Students per web-enabled computer • Internet access in schools (Global Competitiveness Index) • Percentage of schools with shortage of internet connectivity (PISA 2012 School Questionnaire) • Percentage of schools with shortage of computers for instruction (PISA 2012 School Questionnaire)	• **OECD** • UNESCO • UNESCO • WEF • OECD • OECD
	Financial literacy	• **PISA 2012 Financial Literacy Index**	• **OECD**
	Cultural and civic literacy	• **ICCS score** • CivEd test score • World Governance Indicators: Rule of Law, Voice and Accountability and Government Effectiveness • Percentage of students communicating with parents about social and cultural issues • Percentage of students with possessions related to classical culture • Frequency of going to cinema, live performances, cultural sites or attending live sport events	• **IEA** • IEA • World Bank • EU (Eurostat data)
Competencies	**Critical thinking/ problem-solving**	• **PISA 2012 Problem-Solving score**	• **OECD**
	Creativity	• **PISA 2012 mathematics formulate subscore** • International Innovation Index • Global Innovation Index • Global Creativity Index • Creative Class Share	• **OECD** • BCG, NAM • INSEAD, WIPO • MPI • MPI
	Communication	• *No indicators available*	• N/A
	Collaboration	• Self-reported score on university-company research collaboration • Self-reported score on cooperation in labour employment relations	• World Bank

	Skill	Indicator	Source
Character qualities	**Curiosity**	• **PISA 2012 Problem-Solving – Acquisition of Knowledge Subscale**	• **OECD**
	Initiative	• Total early stage entrepreneurial activity (% of working age population both about to start an entrepreneurial activity and that have started one from a maximum of three and a half years) • Established business ownership rate (% of 18-64 population who are currently owner-manager of an established business) • National Expert Survey Index (combination of indicators with significant impact on national entrepreneurship)	• GEM
	Persistence/grit	• Self-reported measure of perseverance (PISA Student Questionnaire) • Total Early Stage Entrepreneurial Activity (GEM)	• OECD
	Adaptability	• *No indicators available*	• N/A
	Leadership	• Quality of management schools (2010) • Reliance on professional management (2010)	• World Bank
	Social and cultural awareness	• Ethnic fractionalization index (2003) • Cultural diversity index (2003)	• James Fearon, Stanford University

Factors influencing indicator selection include broad country coverage, direct skill measure and independent assessment.

***bold** denotes indicator selected to measure skill performance*

Indicators considered and used to estimate educational factors holding countries back:

Education factors	Definition	Indicators
Policy Enablers	Standards that govern K-12 education	• **Number of years of mandatory education (UNESCO)** • Satisfaction with education policy
Human Capital	Teacher quality, training and expertise	• **Number of students per trained teacher, primary**[17] • Number of students per trained teacher, secondary • Number of students per teacher • Teachers working in schools that use some kind of formal appraisal • Average years of working experience as a teacher in total • Teachers who report high need to develop ICT skills for teaching (%) • Teaching time per week (hours) Ideal quality metric would have included: • % of teachers coming from top tier universities • salary data for teachers relative to other jobs with same qualifications
Financial Resources	Importance of education in public budgets	• **Government expenditure per primary student (constant PPP$) (UNESCO)** • Government expenditure on education as % of GDP (%) • Government expenditure per secondary student (constant PPP$)
Technological Infrastructure	Access to new digital tools and content via the internet	• **Internet access in schools (World Economic Forum)** • Mobile broadband penetration • Household broadband penetration • Population using the internet (%)

Other factors, such as socioeconomic status and conflict, also present significant challenges to educational attainment.

bold *denotes indicator selected to measure skill performance*

Sources: OECD, UNESCO, American Educational Research Association.

[17] Calculated using UIS data: Enrollment in primary education [number] / (teachers in primary education [number] x teachers in primary education who are trained [%]). Calculated using Teacher Quality Opportunity Gap and National Achievement data for countries without UIS data for primary teacher education rates.

Appendix 4: Countries with available skill data included in the report

High-income OECD	High-income non-OECD	Upper-middle income	Lower-middle income	Low-income
Australia	Shanghai-China[18]	Albania	El Salvador	Kenya
Austria	Croatia	Argentina	Georgia	Malawi
Belgium	Cyprus	Azerbaijan	Guatemala	Mozambique
Canada	Hong Kong	Botswana	Indonesia	Tanzania
Chile	Latvia	Brazil	Kyrgyzstan	Uganda
Czech Republic	Liechtenstein	Bulgaria	Lesotho	Zimbabwe
Denmark	Lithuania	Colombia	Moldova	
Estonia	Macao	Costa Rica	Nicaragua	
Finland	Malta	Dominican Republic	Paraguay	
France	Qatar	Ecuador	Swaziland	
Germany	Russia	Hungary	Vietnam	
Greece	Singapore	Jordan	Zambia	
Iceland	Trinidad and Tobago	Kazakhstan		
Ireland	United Arab Emirates	Malaysia		
Israel	Uruguay	Mauritius		
Italy		Mexico		
Japan		Montenegro		
Luxembourg		Namibia		
Netherlands		Panama		
New Zealand		Peru		
Norway		Romania		
Poland		Serbia		
Portugal		Seychelles		
Slovak Republic		South Africa		
Slovenia		Thailand		
South Korea		Tunisia		
Spain		Turkey		
Sweden				
Switzerland				
United Kingdom				
United States				

Sources: World Bank; project team analysis.

[18] Shanghai is grouped in high-income non-OECD due to its income level. (PISA reports China data for Shanghai only.)

Appendix 5: A comparison of performance data across tests

Many countries use widely varying measures to assess similar skills, making comparisons between countries' absolute scores on comparable tests difficult. To increase the number of countries with comparable data for literacy, numeracy and scientific literacy, we conducted a crosswalk analysis, which allows researchers to compare results on tests of comparable skills that use widely different scales. For countries in Africa and Latin America that had taken only the SACMEQ or LLESE tests and not the PISA test, we devised a way to convert those region-specific test scores into the equivalent of PISA scores. We looked at the handful of countries in those areas that had taken both PISA and either of the SACMEQ or LLESE tests in 2009 or 2012, in order to calculate an average conversion factor from one of the two regional tests into PISA. We then applied that conversion factor to SACMEQ and LLESE scores to translate them into PISA scores. Since we did not have access to the raw data, we assumed that the statistical distribution of the converted scores corresponded to the distribution of the original scores. The methodology allowed only for a ranking-based comparison of the countries studied, not an absolute score assessment. We therefore have not provided the converted scores for comparison but rather used percentile ranks. This approach draws on the more advanced methodology demonstrated by Altinok and Murseli,[19] as well as Hanushek, Peterson and Ludger,[20] and it is intended to provide an indicative comparison among countries rather than a rigorous assessment of relative performance.

As a result of the analysis, we increased the sample size from 72 to 91 countries. In particular, coverage for the lower-middle-income cluster increased from two to 12 countries and coverage for the low-income cluster increased from zero to six countries.

[19] Altinok, Nadir and Hatidje Murseli. "International Database on Human Capital Quality." Economics Letters 96, no. 2. 2007; Altinok, Nadir. "A New International Database on the Distribution of Student Achievement." 2011. United Nations Educational, Scientific and Cultural Organization (UNESCO).

[20] Hanushek, Eric A., Paul E. Peterson and Ludger Woessman. "Achievement Growth: International and U.S. State Trends in Student Performance." Harvard Kennedy School of Government. 2012.

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