



NMC/CoSN Horizon Report > 2017 K-12 Edition

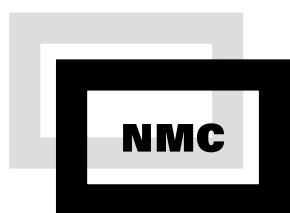


The *NMC/CoSN Horizon Report: 2017 K-12 Edition* examines emerging technologies for their potential impact on and use in teaching, learning, and creative inquiry in schools.



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The NMC/CoSN Horizon Report: 2017 K–12 Edition

is a collaboration between the NEW MEDIA CONSORTIUM and the CONSORTIUM for SCHOOL NETWORKING.

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Photographs

Front Cover: Courtesy of Norton Gusky

Inside Front Cover: Croatian Future Classroom courtesy of Arjana Blazic

Back Inside Cover: Courtesy of Norton Gusky

Back cover: Courtesy of Norton Gusky

Foreword

mindSpark Learning is proud to partner on the publication of the *NMC/CoSN Horizon Report: K–12 Edition* for back-to-back years. By providing professional learning for teachers and school leaders, mindSpark Learning scales the impact of innovative school cultures, supports educators in implementing authentic learning experiences, and ultimately helps empower students to think critically, collaborate, communicate, and develop creative solutions — all with the end goal of increased student engagement and ignited teachers who send their students home feeling like someone is entirely invested in their learning and the impact it will have on their future.

As is indicated by the research herein, some key trends are already accelerating the rate at which technology is being adopted in K–12 education. For example, *coding as a literacy* and *the rise of STEAM learning* are at the forefront of what many schools are focusing on as educational platforms for their students. These are foundational aspects of what mindSpark Learning offers in many trainings and workshops; preparing students for the careers of the future is and always has been a main pillar of education, and clearly coding language and STEAM learning are pivotal to the future of students. By partnering with industry leaders like [Code.org](https://code.org), we increase our outreach and diversify our offerings to ensure an impact that is both broad and deep. Starting with what we can control now allows us the ability to address the coming trends in technology for education with more efficiency and effectiveness.

As schools adopt more offerings that focus on increasing students' literacy in coding, and on informing them to be cognizant of how important learning in STEAM will be in their future, they also need to be aware of the trends that are leading to a *growing focus on measuring learning* in unique ways and a need for *redesigning learning spaces* to better engage students in creative and digital experiences. This is how mindSpark Learning

is able to enact many of the research findings in this report ourselves; we don't think only of what is possible now, but also of what will be possible tomorrow, and in the years to come. In other words, it is clear that there need to be more robust ways to assess student learning, assessments that go beyond standardized test scores and instead focus on the concepts, skills, and abilities students need to master in order to be successful when they start their careers.

mindSpark Learning offers workshops that focus on bringing this sort of growth mindset to the school and classroom, with the goal of empowering educators to think critically themselves, so they can in turn enlist these strategies in their curricula. It's not about how well a student scores on a test anymore — and it shouldn't be. It is instead about how well a student is able to solve complex problems that require thinking beyond what is needed to answer a multiple-choice question. Students need to be taught to solve real-world problems, with real-world strategies, and then assessed on their ability to do so. One way to do this is to provide a learning environment with space that allows for these types of real-world problems to be conducted and taught. Whether that's through flexible furniture, open concept classrooms, or the use of different classrooms throughout the day, a focus on creating space that allows for the diverse needs of students to be met, both physically and mentally, is key.

The trends above are crucial to the way mindSpark Learning conducts work with both school leaders and educators. This is consistent with our role as a catalyst in movements that bring *cultures of innovation* and *deeper learning approaches* to schools across the nation; reimaged learning spaces and advanced assessment strategies are pivotal to the way schools increase their innovative impact and offer learning that goes beyond surface-level knowledge.

If a school adopts a culture of innovation, then deeper learning is a possibility, plain and simple. That kind of change starts at the top and moves throughout the rest of the school systematically, eventually contributing to a mindset that is based on challenging students to take the initiative with how deep they go into learning a specific area of interest. By putting teachers and school leaders in these scenarios first, and tasking them to challenge the way they have always conducted their learning with something that may make them feel uncomfortable, we are empowering them to consider variables that may have seemed out of reach before. This in turn creates a growth mindset that uses creativity and failure as the path to truly authentic learning; in other words, fail fast and pivot. By adopting these kinds of mindsets at a cultural level, schools will begin to notice that teachers are more engaged with what they are teaching, and that teachers are delivering the type of learning that will eventually lead students to take ownership of how deeply they investigate an area of interest.

Of course, there are always challenges that impede the progress of truly game-changing initiatives, and implementing the strategies detailed in all of the above is no easy task. As detailed in this report, the challenges run the gamut from solvable to difficult and ultimately to wicked. Solvable challenges are *authentic learning experiences* and *improving digital literacy* because we are already seeing solutions to these issues. In other words, to give students authentic learning experiences, we need only offer them projects that focus on real-world problems and give them access to a real-world audience for feedback and critiques. Training and supporting educators to use these strategies in their classroom is as simple as providing an experience that mirrors and complements what they can offer their students. Digital literacy is another simple solve as well because all it requires is the knowledge of how to appropriately interact with the digital world. Even adults struggle with safety, professionalism, and accountability on the internet, but that kind of knowledge is key to the expansion of the internet, and is one of the many training focuses at mindSpark Learning.

Beyond the solvable issues are obviously the difficult issues like helping teachers to reimagine their role in the classroom and helping students to understand the process of computational thinking. By training teachers to become a part of the classroom, rather than the sole focus of the classroom, we are increasing student engagement and reimagining the way they learn. In turn, students learn from the cyclical perspective that a lot of industries use today. Computer science demand is obviously a big part of this thought process, and if we start teaching students about coding and computer

software language at a young age, we empower them to seek the careers of the future down the road, and learn to teach machines to work in tandem with humans.

As we move past the difficult challenges and begin to deal with the wicked challenges as identified in the report, we start to see conventions become the norm, and innovation a challenging influence to enact. How do we solve the achievement gaps associated with demographic and geographic issues? How do we sustain an innovative culture when leadership changes? These are the questions that are at the forefront of why the education system is so difficult to evolve. At mindSpark Learning we believe in answering those questions; we believe in developing systems and programs that are capable of enacting the kind of change necessary to transform an obsolete system that has toiled through the past 100 years along the same path without evolving to keep up with the times.

That kind of change starts with important and exciting developments that are the future of technology and creativity in education. It starts by training students how to program robots to complete a task through coding. It starts with makerspaces that bring creativity back into the classroom and empower students to think beyond traditional solutions, and critically develop solutions that are truly authentic to their style of learning. It starts with sophisticated data analytics that allow for real-time data-mining so that instruction can be driven by authentic student information in the moment, for the moment.

That kind of change starts with virtual reality that places students at the scene of a potential learning opportunity — virtual reality that allows students to actually see inside the human body, explore the prehistoric era, visualize early civilizations, encounter expeditions on Mt. Everest, and truly conceptualize learning on a whole new level. Who knows? It may even start with artificial intelligence that is capable of solving even the most complex problems. The point is, we are on the cusp of something special, an era where humans will work in tandem with the machines they build to create a future where humanity is capable of accomplishing incredible feats. All we have to do is help students build that world.

mindSpark Learning is proud to be on the cutting edge of where education is heading, and to partner with organizations — like NMC and CoSN — that focus on researching the best ways to implement these kinds of cutting-edge ideas into schools and classrooms at every level.

Kellie Lauth, CEO
mindSpark Learning
August 4, 2017

Executive Summary

What is on the five-year horizon for schools? Which trends and technology developments will drive educational change? What are the critical challenges and how can we strategize solutions? These questions regarding technology adoption and educational change steered the discussions of 61 experts to produce the *NMC/CoSN Horizon Report: 2017 K–12 Edition*, in partnership with the Consortium for School Networking (CoSN) and made possible by mindSpark Learning.

This *NMC Horizon Report* series charts the five-year impact of innovative practices and technologies for K–12 education (primary and secondary education) across the globe. With more than 15 years of research and publications, the NMC Horizon Project can be regarded as education's longest running exploration of emerging technology trends and uptake.

Six key trends, six significant challenges, and six developments in educational technology profiled in this report are poised to impact teaching, learning, and creative inquiry in K–12 education. The three sections of this report constitute a reference and technology planning guide for educators, school education leaders, administrators, policymakers, and technologists. These highlights capture the big picture themes of educational change that underpin the 18 topics:

1 Advancing progressive learning approaches requires cultural transformation. Schools must be structured to promote the exchange of fresh ideas and identify successful models with a lens toward sustainability — especially in light of inevitable leadership changes.

2 Learners are creators. The advent of makerspaces, classroom configurations that enable active learning, and the inclusion of coding and robotics are providing students with ample opportunities to create and experiment in ways that spur complex thinking. Students are already designing their own solutions to real-world challenges.

3 Inter- and multidisciplinary learning breaks down silos. School curricula are increasingly making clear connections between subjects like science and humanities, and engineering and art, demonstrating to students that a well-rounded perspective and skill set are vital to real-world success.

4 The widespread use of technology does not translate into equal learner achievement. Technology is an enabler but does not alone compensate for gaps in student engagement and performance attributable to socioeconomic status, race, ethnicity, and gender.

5 Continuously measuring learning is essential to better understanding learners' needs. Analytics technologies are providing teachers, schools, and districts with both individual and holistic views of student learning, informing strategies for serving at-risk and gifted populations.

6 Fluency in the digital realm is more than just understanding how to use technology. Learning must go beyond gaining isolated technology skills toward generating a deep understanding of digital environments, enabling intuitive adaptation to new contexts and co-creation of content with others.

7 Authentic learning is not a trend — it is a necessity. Hands-on experiences that enable students to learn by doing cultivate self-awareness and self-reliance while piquing curiosity. Virtual reality and makerspaces are just two vehicles for stimulating these immersive opportunities.

8 There is no replacement for good teaching — the role is just evolving. No matter how useful and pervasive technology is, students will always need guides, mentors, and coaches to help them navigate projects, generate meaning, and develop lifelong learning habits. School cultures must encourage, reward, and scale effective teaching practices.

9 Schools are prioritizing computational thinking in the curriculum. Developing skills that enable learners to use computers to gather data, break it down into smaller parts, and analyze patterns will be an increasing necessity to succeed in our digital world. While coding is one aspect of this idea, even those not pursuing computer science jobs will need these skills to work with their future colleagues.

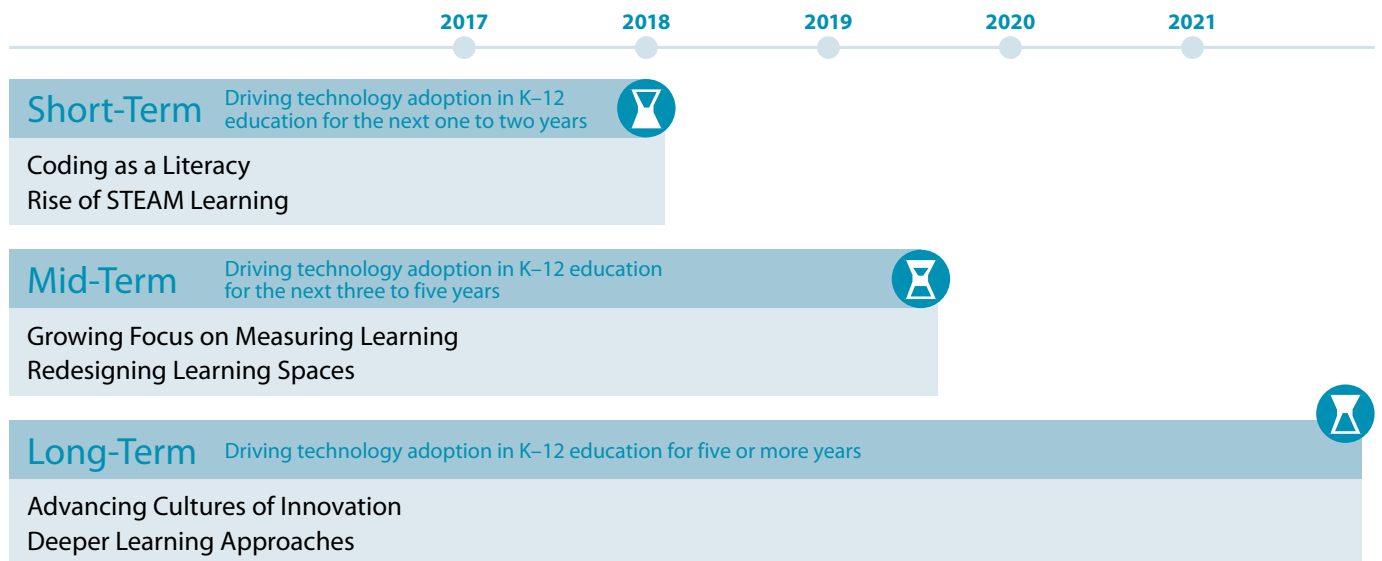
10 Learning spaces must reflect new approaches in education. The pervasiveness of active learning pedagogies is requiring a shift in how learning environments are being designed. Emerging technologies such as making, mixed reality, and the Internet of Things are requiring more flexible and connected plans.

It is our hope that this analysis will help to inform the choices that schools are making about technology to improve, support, or extend teaching, learning, and creative inquiry. K–12 leaders worldwide look to NMC

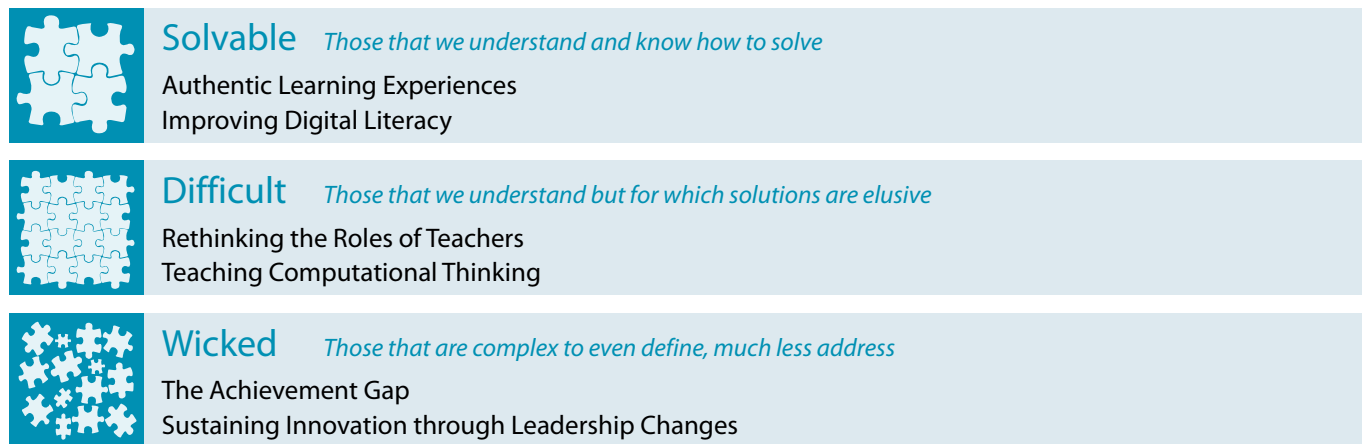
Horizon Project publications as strategic technology planning references, and it is for that purpose that the *NMC/CoSN Horizon Report: 2017 K–12 Edition* is presented.

NMC/CoSN Horizon Report > 2017 K–12 Edition at a Glance

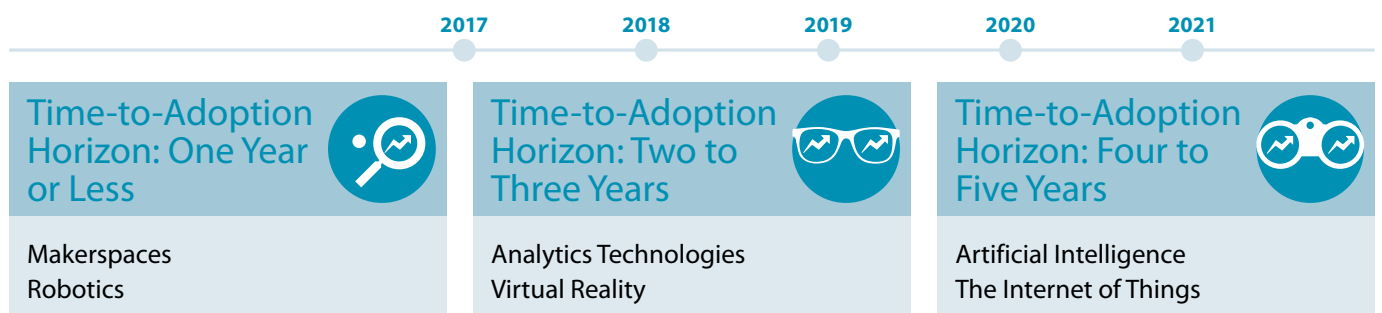
Key Trends Accelerating Technology Adoption in K–12 Education



Significant Challenges Impeding Technology Adoption in K–12 Education



Important Developments in Educational Technology for K–12 Education



Introduction

The *NMC/CoSN Horizon Report: 2017 K–12 Edition* was produced by the NMC in collaboration with CoSN and made possible by mindSpark Learning. The internationally recognized *NMC Horizon Report* series and regional *NMC Technology Outlook* series are part of the NMC Horizon Project, a comprehensive effort established in 2002 that identifies and describes important developments in technology poised to have a large impact on technology planning and decision-making in education around the globe. Each of the four global editions of the *NMC Horizon Report* — higher education, K–12 education, museum, and library — highlights six trends, six challenges, and six developments in technology or practices that are likely to enter mainstream use within their focus sectors over the next five years.

In the pages that follow, 18 topics selected by the 2017 K–12 Expert Panel related to the educational

applications of technology are examined. The topics are placed directly in the context of their likely impact on the core missions of schools and are detailed in succinct, non-technical, and unbiased presentations. Each has been tied to essential questions of relevance or policy, leadership, and practice.

To plan for the future, it is important to look back. In reflecting on the past 15 years of the NMC Horizon Project, larger themes have emerged. Certain topics such as deeper learning approaches and makerspaces reappear, regularly voted into the report by a now vast body of K–12 education leaders and technologists. The tables below show the findings from the past five K–12 editions as well as the 2017 edition. (In some cases, for consistency, the topic names have been slightly modified from the report where they originally appeared.) Also noteworthy is the inclusion of rethinking the roles of educators as both a trend and a challenge; initially categorized as a trend, a previous expert panel moved to recategorize it as a challenge.

Six Years of the *NMC/CoSN Horizon Report: K–12 Edition*

Key Trends	2012	2013	2014	2015	2016	2017
Deeper Learning Approaches						
Blended Learning Designs						
Rethinking How Schools Work						
Rethinking the Roles of Educators						
Redesigning Learning Spaces						
Coding as a Literacy						
Students as Creators						
Proliferation of Open Educational Resources						
Rise of Bring Your Own Device						
Rise of STEAM Learning						
Collaborative Learning						
Advancing Cultures of Innovation						
Growing Focus on Measuring Learning						
Rapid Acceleration of Intuitive Technology						
Impact of Social Media on Scholarship and Communication						
Importance of Technology Skills						
Ubiquitous Learning						

Significant Challenges	2012	2013	2014	2015	2016	2017
Authentic Learning Experiences						
Personalizing Learning						
Rethinking the Roles of Teachers						
Teaching Complex Thinking						
Institutional Barriers, a.k.a. "The System"						
The Achievement Gap						
Scaling Teaching Innovations						
Improving Digital Literacy						
Competition from New Models of Education						
Sustaining Innovation through Leadership Changes						
Advancing Digital Equity						
Integrating Technology in Teacher Education						
Safety of Student Data						
Keeping Formal Education Relevant						
Lack of Digital Media for Formative Assessment						
Ongoing Professional Development for Teachers						
Blending Formal and Informal Learning						

Developments in Technology	2012	2013	2014	2015	2016	2017
Makerspaces						
Wearable Technology						
Analytics Technologies						
Artificial Intelligence						
Robotics						
Virtual Reality						
The Internet of Things						
BYOD						
Cloud Computing						
Games and Gamification						
3D Printing						
Mobile Learning						
Online Learning						
Adaptive Learning Technologies						
Digital Badges						
Open Content						
Virtual and Remote Laboratories						
Augmented Reality						
Natural User Interfaces						
Personal Learning Environments						
Tablet Computing						

In observing the numerous overlaps from edition to edition, it is important to note that while topics may repeatedly appear, they represent only the broad strokes of educational change; each trend, challenge, and technology development evolves over time, with fresh perspectives and new dimensions revealed every year. For example, both mobile and online learning today are not what they were yesterday. Virtual reality, chatbots, and immersive apps have added more functionality and greater potential for learning.

The *NMC Horizon Report* format was revised in 2014 to expand on the trends and challenges that frame technology adoption. This change was grounded in the reality that technology alone cannot cultivate education transformation; better pedagogies and more inclusive education models are vital solutions, while digital tools and platforms are enablers and accelerators. Further, the way in which society is evolving inherently impacts how technology is used as well as the curricula schools deliver. Prior to the 2014 edition, trends and challenges were not placed in horizons; thus, the table views do not capture changes over time in length of impact or scope of difficulty, respectively.

Individual topics are published as two-page spreads to make them useful as stand-alone essays and guides, but generating a more holistic vision of how they all coalesce is becoming increasingly important. In some instances, the challenges represent the obstacles hindering positive trends from scaling and the technologies are accelerators, revealing a convergence between all three sections.

Taken together, the topics featured in the report from year to year tell a larger story about the overarching themes driving progress in — or impeding — teaching, learning, and creative inquiry. Each topic can be placed into one or more of six meta-categories that reflect movements in K–12 education. These meta-categories are also reflected in the *NMC Horizon Report: Higher Education* series to generate a consistent view of teaching and learning across students' entire journeys.



Expanding Access and Convenience.

People expect to be able to learn and work anywhere, with constant access to learning materials, as well as to each other. Schools have made great strides in generating more methods and platforms for teachers, students, and staff to collaborate and be productive wherever they are. The advent of always-connected devices has provided more flexibility in how, when, and where people learn, and many schools have updated their IT infrastructures accordingly. While mobile and digital learning strategies

have increased over time, disparities in high-speed broadband connectivity and in engagement between different student groups (socioeconomic status, gender, etc.) prompt school leaders to continuously evaluate the affordability, access, and quality of their learning content.



Spurring Innovation

If education is viewed as a vehicle for advancing the global economy, then it must be the North Star that guides societies to the next big thing, illuminating new ideas that solve pressing challenges and creating opportunities to shape a better future. In this sense, even K–12 institutions can be incubators of inventions and developments that foster positive trends, as well as the most important product of all: student graduates who not only are prepared for college and for fulfilling evolving job market needs, but who also redefine and improve the environments they enter. Advancing cultures of entrepreneurial thinking and designing new forms of artificial intelligence are just two of many areas of K–12 education that are spreading innovation.



Fostering Authentic Learning

Project-based learning, challenge-based learning, and competency-based learning — all of these pedagogical trends are in service of creating richer and more hands-on, real-world experiences for students. As schools prioritize active learning over rote learning, students are being viewed in a new light. The embedding of maker culture in K–12 education has made students active contributors to the knowledge ecosystem rather than merely participants and consumers of knowledge. They learn by experiencing, doing, and creating, demonstrating newly acquired skills in more concrete and creative ways. Students do not have to wait until graduation to change the world. However, schools continue to be challenged to generate these opportunities in spaces and with paradigms that still lean on traditional practices.



Tracking and Evaluating Evidence.

What good is a new approach or technology deployment if the results are not carefully measured and analyzed, with the curriculum adjusted based on the results? Schools are becoming more adept at capturing a bevy of data. This same principle has been applied to tracking student performance, engagement, and behavior and leveraging those data to inform decision-making

across classes, schools, and districts. This information is also fueling more personalized learning experiences through adaptive learning tools that analyze areas for improvement and deliver tailored content to each student accordingly. As this data-driven theme proliferates in K–12 education, leaders must consider how to scale the data in a way that presents a more holistic picture of student success. Embracing a culture of sharing that breaks down silos while maintaining ethical and privacy standards will be paramount.



Improving the Teaching Profession

The emphasis on more hands-on, technology-enhanced learning has impacted every facet of school life, with teaching as a central force. With students inventing, iterating, and collaborating regularly, teachers have been transplanted from their position as “sage on the stage” to “guide on the side.” There is a need for mentoring and coaching as students work through complex problems to explore new frontiers and gain concrete skills. As student-led class discussions delve deeper into the material, teachers must balance the student-centered approach with subtle but effective facilitation. Schools that recognize and scale positive teaching practices are a necessity. Further, just as there is a need to advance digital literacy among students, teachers must also engage in ongoing professional development, with support from schools.



Spreading Digital Fluency

Technology and digital tools have become ubiquitous, but they can be ineffective or dangerous when they are not integrated into the learning process in meaningful ways. Both higher education and the contemporary workforce call for digital savants who can seamlessly work with different media and new technologies as they emerge. A major element of fostering this fluency is recognizing that simply understanding how to use a device or certain

software is not enough; teachers, staff, and students must be able to make connections between the tools and the intended outcomes, leveraging technology in creative ways that allow stakeholders to more intuitively adapt from one context to another. Ownership of this movement must be shared and supported among school leaders and practitioners because digital fluency is an important thread that runs through practically every facet of teaching and learning.

In the report that follows, each topic will have icons that appear next to it, indicating the above meta-categories to which it belongs, in order to more clearly illuminate the connections between topics. The report’s first two sections focus on an analysis of the trends driving technology decision-making and planning, and the challenges likely to impede the adoption of new technologies, respectively. Each includes an explicit discussion of the trend or challenge’s implications for policy, leadership, and practice in schools and K–12 organizations. The inclusion of these three elements acknowledges that it takes a combination of governance, vision, and action to advance positive trends and surmount pressing challenges. Relevant examples and readings conclude each topic for further elaboration.

The report’s third section focuses on important developments in technology — consumer technologies, digital strategies, enabling technologies, internet technologies, learning technologies, social media technologies, and visualization technologies — all positioned to impact K–12 education over the next five years. Each development contains a discussion of its relevance to teaching, learning, or creative inquiry and concludes with a set of project examples and further readings.

Taken together, the three sections constitute a straightforward guide for strategic planning and decision-making for K–12 education leaders across the world.

Key Trends Accelerating Technology Adoption in K–12 Education

The six trends described in the following pages were selected by the project's expert panel in a series of Delphi-based voting cycles, each accompanied by rounds of desktop research, discussions, and further refinements of the topics. These trends, which the members of the expert panel agreed are very likely to drive technology planning and decision-making over the next five years, are sorted into three movement-related categories — long-term trends that typically have already been affecting decision-making and will continue to be important for more than five years; mid-term trends that will likely continue to be a factor in decision-making for the next three to five years; and short-term trends that are driving educational technology adoption now but will likely remain important for only one to two years, either becoming commonplace or fading away in that time.

While long-term trends have already been the topic of many education leaders' discussions and extensive research, short-term trends often do not have an abundance of concrete evidence pointing to their effectiveness and future directions. All of the trends listed here were explored for their implications for K–12 education in a series of online discussions that can be viewed at go.nmc.org/2017-k12-trends.

The NMC Horizon Project model derived three meta-dimensions that were used to focus the discussions of each trend and challenge: policy, leadership, and practice. Policy, in this context, refers to the formal laws, regulations, rules, and guidelines that govern schools; leadership is the product of experts' visions of the future of learning, based on research and deep consideration; and practice is where new ideas and pedagogies take action, in schools and related settings. Below are summaries of the six key trends that will be explored in more depth in this section, with citations and resources included.

Long-Term Trends: Driving technology adoption in K–12 education for five or more years.

Advancing Cultures of Innovation. Innovation in schools has sparked a trend toward learner-centered paradigms in which students build critical thinking skills in environments that mimic the real world. Entrepreneurship, collaboration, project-based learning,

and creativity are hallmarks of this transformational movement, which often falls under the umbrella of STEAM education.¹ Government, school, and NGO leaders who have pioneered effective new models are beginning to share and replicate best practices regionally and internationally.² Many of these emerging models are rooted in principles that uphold character development, grit, and design, which encourage learners to work hard toward their goals and bring their ideas to fruition.³ Private–public partnerships have emerged as education leaders find ways to engage learners in authentic experiences that are relevant to their future, while businesses seek pipelines for highly skilled, global citizens.⁴ This trend acknowledges that every big idea has to start somewhere, and both students and teachers should be equipped with the mindsets and tools needed to spark real progress.

Deeper Learning Approaches. There is an embedded emphasis in K–12 education on deeper learning approaches, defined by the William and Flora Hewlett Foundation as the mastery of content that engages students in critical thinking, problem-solving, collaboration, and self-directed learning.⁵ To remain motivated, students need to be able to grasp how existing knowledge and new skills can impact the world around them. Pedagogical approaches that shift the paradigm from passive to active learning help students to develop original ideas, improve information retention, and build higher-order thinking skills.⁶ These approaches include problem-based learning,⁷ project-based learning,⁸ challenge-based learning,⁹ and inquiry-based learning,¹⁰ which encourage creative problem-solving and actively implementing solutions. As the enabling role of technologies in learning crystallizes, educators are leveraging these tools to connect curricula with real-world applications.

Mid-Term Trends: Driving technology adoption in K–12 education for the next three to five years

Growing Focus on Measuring Learning. This trend describes the exploration and evaluation of a wide variety of assessment tools used to measure academic readiness, school progress, skill acquisition, and student achievement. The advance of data mining software and online learning environments has compelled many districts to incorporate learning analytics and

visualization techniques that can provide data in an accessible and timely manner.¹¹ School leaders believe that these new systems help them keep their finger on the pulse of their institutions for executive decision-making while empowering teachers to make data-informed choices for their instruction and lesson planning in the classroom. Many educators are taking advantage of the emergence of digital tools such as PearDuck, EdPuzzle, and ThinkThrough Math to monitor student achievement in real time.¹² Another dimension of this trend is the idea of finding innovative ways to track development of soft skills such as creativity and collaboration — soft skills deemed necessary for today's workforce.

Redesigning Learning Spaces. As conventional teaching models evolve and emerging technologies gain a solid foothold in classrooms worldwide, formal learning environments require an upgrade to reflect the 21st-century practices taking place within them. Education has traditionally relied on teacher-centric approaches where lectures were the main source for knowledge transference. The role of teachers is evolving, as seen later in this report, to support more student-centric approaches to better prepare learners for the future workforce, and new approaches to classroom design are supporting this shift.¹³ Active learning spaces have the characteristics of being mobile, flexible, varied, and connected — they value tables, stations, and hubs over rigid structures. Additionally, innovative thinking in architecture and space planning is influencing the sustainable design and construction of new school infrastructures that can significantly improve learning by enhancing student well-being with an eye to conserving energy.¹⁴ Schools can look to innovative examples for inspiration as this trend continues to develop.

Short-Term Trends: Driving technology adoption in K–12 education for the next one to two years

Coding as a Literacy. Coding refers to a list of rules, written in one of numerous programming languages, that instruct a computer to do what a user wants it to do: perform a sequence of instructions, repeat a sequence of instructions a prescribed number of times, and test whether a sequence was performed correctly.¹⁵ Many educators believe that coding helps children to understand how computers work, to communicate their thoughts through structure and logic, to think critically, and to be successful in the increasingly digital workplace.¹⁶ Code.org recently stated that computing occupations are among the fastest growing and best paying jobs in the US, and that there are currently 500,000 unfilled jobs in that sector.¹⁷ To better prepare

learners from a young age, an increasing number of school leaders and technologists are making the case for embedding coding into K–12 curricula.

Rise of STEAM Learning. In recent years, there has been a growing emphasis on developing stronger science, technology, engineering, and mathematics (STEM) curricula and programs; these disciplines are widely viewed as the means to boost innovation and bolster national economies. In response to the focus on STEM learning, many educators are advocating that integrating the arts, design, and humanities into STEM curricula is essential to build interpretive and creative skills. This notion has fostered the STEAM learning movement, in which the A stands for “art+.” Engaging students in a multi- and interdisciplinary learning context breaks down barriers that have traditionally existed between different classes and subjects and offers learners opportunities to make new connections. Educators are working together across disciplines to develop integrative projects and goals that provide students with a perspective on how a wide variety of knowledge and skill sets tie into each other in the real world.¹⁸

The following pages provide a discussion of each of the trends highlighted by this year's expert panel, including an overview of the trend, its implications, and a set of curated recommendations for further reading on the topic.

Advancing Cultures of Innovation

Long-Term Trend: Driving technology adoption in K–12 education for five or more years



Innovation in schools has sparked a trend toward learner-centered paradigms in which students build critical thinking skills in environments that mimic the real world. Entrepreneurship, collaboration, project-based learning, and creativity are hallmarks of this transformational movement, which often falls under the umbrella of STEAM education.¹⁹ Government, school, and NGO leaders who have pioneered effective new models are beginning to share and replicate best practices regionally and internationally.²⁰ Many of these emerging models are rooted in principles that uphold character development, grit, and design, which encourage learners to work hard toward their goals and bring their ideas to fruition.²¹ Private–public partnerships have emerged as education leaders find ways to engage learners in authentic experiences that are relevant to their future, while businesses seek pipelines for highly skilled, global citizens.²² This trend acknowledges that every big idea has to start somewhere, and both students and teachers should be equipped with the mindsets and tools needed to spark real progress.

Overview

A focus on school culture is a key thread of this long-term trend. Many educators believe that to sustain innovation, schools' missions must be reinvented to reflect the agile and collaborative mindsets learners will need to thrive in today's world. School leaders are using strong mission and vision statements as the "guiding star" for transforming the culture, curriculum, and operations to support an innovative school model. At the Science Leadership Academy in Philadelphia, a simple mission hones in on the project-based curriculum, upholding reflection as a necessary part of the scientific process; staff gather annually to revisit the core values.²³ Innovative schools prioritize learners and emerging models of education in their foundational statements. The International School Twente in Holland focuses on educating its diverse student population with a competency-based model that encourages character development and international understanding through hands-on projects.²⁴

One factor that is advancing innovation in schools is the emergence of mutually beneficial public and private partnerships. The Toyota USA Foundation recently granted \$1.7 million to the Southwest Independent School District in Texas to support the STEM curriculum at its new high school, which is

located near a truck manufacturing facility. Deemed a Center for Applied Science and Technology and a workforce pipeline, the new campus will feature state-of-the-art labs and a rigorous curriculum that counts for college coursework.²⁵ Government agencies are also spearheading initiatives to encourage innovation. For example, in Egypt, USAID is working with the Ministry of Education to prepare the country's youth for the needs of the modern economy with robust STEM programs. Starting with a pilot in two Cairo high schools, the STEM School Project has expanded to seven schools and will impact 1,000 students, while providing teachers with training in innovative curricula and practices.²⁶

Transforming cultures in schools means recruiting and retaining teachers and school leaders who are ready to pioneer new systems with expertise and an "all-in" mindset. Aalto University and the University of Helsinki have partnered to offer a Diploma in Innovation in Education that is targeted to principals, teachers, administrators, policymakers, and NGO executives. The program focuses on measuring improvements in strategies, implementing a design-oriented approach to learning, and achieving operational excellence in schools.²⁷ In Ireland, Dublin City University's Institute of Education has created a new department called the School of STEM Education, Innovation, and Global Studies to train education leaders in topics that promote innovation and leadership. Intended to help teachers adopt a global and social perspective on their issues, the department offers courses in education for sustainability, global citizenship education, and creativity and entrepreneurship.²⁸

Implications for Policy, Leadership, or Practice

Countries with the highest performing education systems are often guided by agile policies that foster student-centric learning. With its glowing reputation for high PISA scores and other internationally benchmarked assessments, Singapore has drawn attention to its policies, which articulate clear goals for education and are based on core values such as responsible decision-making and critical and inventive thinking. Researchers also point to the strong alignment of teacher preparation institutions, the Ministry of Education, and schools as a key factor of success for the innovative, learner-focused system.²⁹ Many national policies are proving that emerging education initiatives are inclusive of learners from all geographic and demographic backgrounds.

In 1987, the Colombian government adopted Escuela Nueva to transform rural schools into active, flexible, and cooperative learning environments.³⁰ With its highly standardized, self-paced curriculum that includes survival skills and other practical topics, Escuela Nueva has been touted as a “model for the world” and been scaled by governments in 14 other countries.³¹

When adopting progressive programs, districts and schools need guidance and concrete goals in order to sustain innovation. Launched in 2011 by US President Barack Obama, Digital Promise is a bipartisan, nonprofit organization that convenes education experts to build systems of leadership that are designed to advance new initiatives.³² Their recent partnership with American auto manufacturer GM on the STEM Impact Compass aims to remove the barriers that keep young people from engaging in technology and engineering fields by creating curricula to train teachers in computational thinking.³³ The Center for Universal Education at the Brookings Institution has compiled an extensive study examining the most promising innovations that will benefit marginalized youth all over the world. The report is focused on four main areas — hands-on, minds-on learning; elevating the education workforce; streamlining schools; and activating communities for accountability and delivery — with the goal of informing the International Commission on Financing Global Education Opportunity on transformational paradigms.³⁴

Innovative schools have challenged the status quo by providing students with leadership opportunities to build strength of character, communication, and social and emotional skills.³⁵ At the Irvington Union Free School District in New York, students apply through a competitive grant process to the Student Innovation Fund to realize their plans for improving the school community. Although these projects are not tied to specific learning objectives, they work alongside other project-based initiatives in the district that encourage learners to be passionate and inventive about solving problems in their surroundings.³⁶ In Austin, Texas, Student Inc. is one of the nation's first public K–12 entrepreneurship programs. Beginning in elementary and continuing through middle school, the culmination of students' experiences takes place at David Crockett High School where they participate in an incubator class and compete for funding to launch their businesses.³⁷

For Further Reading

The following resources are recommended for those who want to learn more about advancing cultures of innovation:

\$2 Million in Talent Ready Utah Grants Awarded for Workforce Development Programs

go.nmc.org/talentut

(Department of Workforce Services, 16 June 2017.) Talent Ready Utah is a statewide initiative to increase

the number of businesses in Utah that have high-quality, authentic learning partnerships with education institutions. Funds will be used to implement innovative models of learning including project-based learning, coding camp, and work–study programs.

Adding These Two Letters to STEM Education Can Make a Big Difference

go.nmc.org/stemie

(Danny Briere, *Getting Smart*, 10 February 2017.) Adding invention and entrepreneurship to STEM may attract more interest among girls and minorities. The leader of the Connecticut Invention Convention explains how they are building national coalitions to support teachers and schools that are shaping children into problem-solvers.

Developing Entrepreneurship in Primary Schools

go.nmc.org/entedu

(María de Lourdes Fármaso-Solís et al., *Teaching and Teacher Education*, May 2017.) This quantitative and qualitative analysis shows that entrepreneurship education, when introduced at an early age, has the potential to improve the socioeconomic status of impacted communities and can increase self-employment in developing countries.

Don't Let Innovation Agenda Run Out of STEAM

go.nmc.org/innaus

(Roy Green, *The Sydney Morning Herald*, 27 October 2016.) The dean of the University of Technology Business School draws comparisons between Israel, a country where entrepreneurship is embedded into the culture, and Australia, which needs a system-wide, integrated STEM curriculum. To address this, the Business School has created the Spark Festival, an opportunity for 1,000 students throughout western Sydney to build and launch STEM and STEAM projects.

Entrepreneurship Education in Technical Secondary Schools in Luxor

go.nmc.org/luxecp

(UN Information Centre in Cairo, 12 February 2017.) As part of UNIDO's IMKAN project, 93 teachers from Luxor technical secondary schools were trained to integrate entrepreneurial skills through UNIDO's Entrepreneurship Curriculum Program (ECP). The ECP has impacted over one million students throughout 11 countries thus far.

How to Create a Culture for Valuable Learning

go.nmc.org/kidcreate

(Katrina Schwartz, *MindShift*, 15 August 2016.) To avoid marginalizing other forms of intelligence, schools need to embrace and extract children's creativity. The thought leader behind a popular education TED Talk believes that the education systems focus too heavily on the world outside school rather than the world within, which can distract young people from discovering their purpose and organic path.

Deeper Learning Approaches

Long-Term Trend: Driving technology adoption in K–12 education for five or more years



There is an embedded emphasis in K–12 education on deeper learning approaches, defined by the William and Flora Hewlett Foundation as the mastery of content that engages students in critical thinking, problem-solving, collaboration, and self-directed learning.³⁸ To remain motivated, students need to be able to grasp how existing knowledge and new skills can impact the world around them. Pedagogical approaches that shift the paradigm from passive to active learning help students to develop original ideas, improve information retention, and build higher-order thinking skills.³⁹ These approaches include problem-based learning,⁴⁰ project-based learning,⁴¹ challenge-based learning,⁴² and inquiry-based learning,⁴³ which encourage creative problem-solving and actively implementing solutions. As the enabling role of technologies in learning crystallizes, educators are leveraging these tools to connect the curriculum with real-world applications.

Overview

Traditional pedagogical approaches have prioritized the development of skills that helped produce industrial workers to address the economic needs of filling rote mechanical and clerical jobs.⁴⁴ Current labor demands are increasingly digital, requiring a shift to more student-centered approaches where technology is used to support deeper learning pedagogies. The 2017 Horizon Expert Panel noted that as 1:1 mobile deployments expand, students have a greater ability to learn anywhere at any time, allowing for more collaboration and facilitating increased access to peers and experts. Once seen as a distraction in the classroom, mobiles are now a powerful tool for advancing learning. Thought leaders have highlighted a growing number of tools that educators can use to leverage the power of personal mobile devices to advance deeper learning. These include Poll Everywhere for immediate feedback, Shutterfly for documenting fieldwork, and Evernote for organization and collaboration.⁴⁵

Deeper learning requires educators around the world to focus on their teaching strategies such that students lead their own inquiry. Experts believe that teachers must also acknowledge the prior experiences students bring to the classroom, helping them integrate and transfer knowledge to new situations, and support their

ability to be aware of their learning and gain confidence in their solutions.⁴⁶ Deeper learning continues to build traction in schools as it becomes increasingly mainstream. The International Society for Technology in Education has listed the student-centered approaches of project-, problem-, and challenge-based learning as 1 of 11 edtech trends to watch in 2017 because these pedagogical frameworks foster greater connectedness to the curriculum and the world outside the classroom.⁴⁷ Project-based learning is being enhanced by technology by: fueling students' curiosity, providing teachers with scaffolding, and facilitating more flipped classroom models.⁴⁸

Since the release of the 2014 report *A Rich Seam: How New Pedagogies Find Deep Learning*, which documented the confluence of new pedagogies, change leadership, and system economics as they accelerated deeper learning approaches in schools, growing evidence is showing that these strategies are becoming increasingly effective in supporting student success.⁴⁹ In 2016, the American Institute for Research released the results from the *Study of Deeper Learning: Opportunities and Outcomes* that set out to show the impact of mature and well-implemented deeper learning opportunities in select schools. They found that students in networked schools achieved higher scores on the global OECD PISA-based test for schools and exhibited higher levels of collaboration skills, greater academic engagement, and higher on-time graduation rates; further, the data showed greater likelihood of college enrollment than in comparison schools. These networked schools applied a wide range of strategies to achieve these positive results including focuses on project-based learning, internship opportunities, formative assessments, and study groups.⁵⁰

Implications for Policy, Leadership, or Practice

Work is under way around the world to develop policies that call for deeper learning approaches in schools. The European Commission is engaging in initiatives to ensure the proper training and support of learners in the European Union. Their document *Communication: A New Skills Agenda for Europe* proposes 10 actions to be undertaken between 2016 and 2018, including recommendations to build lifelong transferable competencies such as teamwork, creative thinking,

and problem-solving.⁵¹ At the state and district level, policies that focus on soft skills attainment continue to spread. The concept of social and emotional learning (SEL), where students overcome emotional and traumatic challenges to persist in their academics, is being explored to strengthen the development of deeper learning competencies across the US.⁵² Washoe County School District, for example, has implemented SEL standards to increase graduation rates to 90% by 2020 and has seen a 75% increase since introducing SEL policies.⁵³

Educational leaders are providing greater support to schools for incorporating deeper learning. The global organization New Pedagogies for Deep Learning (NPDL) is a partnership of 1,000 schools across 10 countries working to build deeper learning knowledge and practice. They work with their network of educators on designing learning approaches that build on students' strengths and needs through real-life problem-solving. NPDL has developed the Deep Learning Competencies, or 6 C's, for students to succeed as lifelong learners; they include collaboration, creativity, and critical thinking, among others.⁵⁴ CoSN is also helping schools leverage technology for authentic problem-solving. Its report *Digital Tools for Problem-Based Learning* chronicles the best practices of school leaders and explains how educators are teaching computational and design thinking; cultivating entrepreneurial mindsets; using digital tools for research, productivity, and assessment; and more.⁵⁵

At the school level, educators can learn from their peers when it comes to implementing deeper learning methods and activities. In Brazil, the Lumiar schools build living curricula with students as collaborators — learners engage in projects, modules, and workshops to address individual and collective needs.⁵⁶ In the Reading the World module, learners use daily newspapers articles to encourage debate, improve writing skills, and create productions.⁵⁷ Tabor Academy in Massachusetts is another space experimenting with rethinking how schools operate to enhance deeper learning. For the 2017–18 school year, the academy will employ a new schedule with a seven-day rotation, featuring an 8:30 a.m. start time and four 75-minute classes. The dean of studies states that they took into consideration sleep patterns, workloads, and stress levels to develop the schedule, which reduces the number of transitions required in a given school day.⁵⁸

For Further Reading

The following resources are recommended for those who wish to learn more about deeper learning approaches:

5 Emerging Trends in Project-Based Learning

go.nmc.org/bie

(Rosie Clayton, BIE, 12 December 2016.) Project-based learning is quickly spreading in schools nationwide. Design thinking, game-based learning, and internships are just some of the trends appearing in learning innovation.

Crazy or Brilliant: Marriage of Deeper Learning and Personalized Learning

go.nmc.org/dlear

(Lydia Dobyns, *Huffington Post*, 14 June 2017.) Instructors hope to merge deeper, authentic learning experiences with personalized learning. Their wish is one powerful platform that will hold learner profiles and a personalized learning path for students.

Instructional Practices for Deeper Learning: Lessons for Educators

go.nmc.org/asia

(Jackie MacFarlane, Dan Aladjem, Christina A. Russell, Asia Society, May 2017.) The national and international consensus surrounding the importance of deeper learning has led to questions on how educators can best facilitate its implementation.

Leveraging the Arts for Deeper Learning

go.nmc.org/dlart

(Aaron Jones, Walton Family Foundation, 16 December 2016.) Arkansas Arts Academy partnered with a national military park so students could investigate a Civil War battlefield for artifacts. Immersing students in this hands-on experience gave them the opportunity to feel more involved and passionate about their learning.

Performance Assessment Resource Bank: Resources for Deeper Learning

go.nmc.org/scope

(Elizabeth Leisy Stosich, Stanford Center for Opportunity Policy in Education, 26 October 2016.) Stanford launched a free bank of high-quality performance assessment resources to engage students in deeper learning. These resources help raise the level of instruction provided by teachers and create opportunities for authentic application of student knowledge and skills.

Who'll Win from the Fourth Industrial Revolution?

go.nmc.org/dlrev

(Nesta, 3 March 2017.) The fourth industrial revolution is rooted in the emergence of new technologies, and it is our job to ensure that we all benefit from it. Involving students in the making and shaping of new technologies allows them to take a leadership role in the revolution.

Growing Focus on Measuring Learning

Mid-Term Trend: Driving technology adoption in K–12 education for the next three to five years



T*his trend describes the exploration and evaluation of a wide variety of assessment tools used to measure academic readiness, school progress, skills acquisition, and student achievement. The advance of data mining software and online learning environments has compelled many districts to incorporate learning analytics and visualization techniques that can provide data in an accessible and timely manner.⁵⁹ School leaders believe that these new systems help them keep their finger on the pulse of their institutions for executive decision-making while empowering teachers to make data-informed choices for their instruction and lesson planning in the classroom. Many educators are taking advantage of the emergence of digital tools such as PearDuck, EdPuzzle, and Think Through Math to monitor student achievement in real time.⁶⁰ Another dimension of this trend is the idea of finding innovative ways to track development of soft skills such as creativity and collaboration — soft skills deemed necessary for today’s workforce.*

Overview

From intelligence assessments to written essays to multiple-choice, tests have become an essential method for collecting data that keep schools accountable. Yet, as more local, national, and state governments mandate standardized testing to support policy initiatives, a number of educators and school leaders have claimed that an overemphasis on these assessments takes away from instructional time and causes undue stress for teachers and mental strain for students.⁶¹ Other critics, including the National Union of Teachers in the UK, believe that standardized tests narrow the curriculum and fail to raise standards while having punitive consequences for schools systems and their stakeholders.⁶² The advance of technology and progressive trends in teaching and learning, however, have given rise to innovative methods of measuring learning, which progressive school leaders believe lead to positive, sustained change in classrooms.⁶³

Learning analytics (LA) has been a key development in the progress of measuring learning in K–12 education. Adopted by schools to improve student learning and optimize educational environments, LA is the collection, analysis, and reporting of data about learners and their contexts. When paired with formative assessment — a type of diagnostic testing that measures students’

understanding while they are learning — LA can garner nuanced insights on student progress and determine gaps in knowledge. Blended and hybrid environments are perceived as the most favorable conditions for schools and districts to track student progress closely because much of the learning takes place online.⁶⁴ Similarly, another emerging approach, competency-based learning, offers a promising alternative to summative assessment by validating student learning through digital portfolios and authentic assessments that have students performing a task or project in a real-world environment.

The concept of implementing academic data to predict student success has already been proved by more established school systems. Chicago public schools, for example, have applied two decades’ worth of data to pinpoint the milestones that matter most for student success in a project called Freshman on Track. With only a “basic” data infrastructure that tracks attendance levels and grades, the urban school system can transform timely data into informed practices that have helped thousands more students graduate over the years.⁶⁵ Orin Murray, the director of technology for UChicago Impact, said that the outcome of the project has nothing to do with the sophistication of the technology but instead with the data’s accessibility to teachers and administrators. These approaches have ignited a productive dialogue about the importance of design, implementation, and application of systems that track student learning, ensuring that this mid-term trend will continue to gain traction in the K–12 community.⁶⁶

Implications for Policy, Leadership, or Practice

As data-based systems for education become more sophisticated, governments at all levels are using these tools to create policies that achieve quality instruction for all. The Australian federal government has been collating data from nearly 10,000 schools using a tool called My School. Launched in 2010, My School tracks student academic performance, socioeconomic backgrounds, and schools’ financial resources, which are presented in annual “report cards” that can be viewed publicly by all schools. The system has since informed policies that target school funding reforms using comparative data taken from My School.⁶⁷ Similarly, California’s State Board of Education launched the California School Dashboard this spring in order to improve schools and target

achievement gaps. The website presents a wide range of data including academic achievement, school climate, student engagement, and funding-derived indicators in addition to standardized testing scores. The dashboard will be instrumental in school accountability measures starting with the 2017–18 school year.⁶⁸

Wide-scale approaches to measuring learning are characteristic in global initiatives that are leading the way. Using data to track educational outcomes is a key part of the UN's Sustainable Development Goals, specifically in its creation of the Global Alliance to Monitor Learning (GAML) to achieve goal 4, quality education.⁶⁹ In the ongoing discussion taking place on the Data for Sustainable Development blog, lead strategists and advisors for Education 2030 discuss assessments and reporting tools that will help align content internationally, collect data produced by learning assessments, and evaluate the robustness of assessment systems.⁷⁰ Another global initiative that aims to improve education worldwide is the Measuring Early Learning Quality and Outcomes (MELQO) initiative.⁷¹ Formed by an international consortium including UNESCO, UNICEF, the World Bank, and the Center for Universal Education at the Brookings Institution, MELQO has been employed in Tanzania to produce data that will help in regional tracking of children's readiness for school.⁷²

Teachers have been the pioneers of implementing new methodologies and tools that evaluate student learning in innovative ways. In three charter schools in Arizona, blended learning models are employed to better serve at-risk students. With fully equipped classrooms, state-provided data-tracking software, and a formative assessment system called Galileo, students in these schools are aware of their progress at all times and are encouraged to think about what they need to do to improve. Teachers reported that these data-oriented tools help them better meet their students' needs by allowing them to focus on the whole child.⁷³ At Chinn Elementary in Missouri, students demonstrate their mastery of outcomes as part of a competency-based model that promotes experiential and collaborative learning. When researching animals, learners created and illustrated books about their subject, and then used D2L's Video Note tool to produce videos about their final projects.⁷⁴

For Further Reading

The following resources are recommended for those who want to learn more about the growing focus on measuring learning:

Building and Leading a School Culture That Values Data-Informed Dialogue to Improve Student Learning

go.nmc.org/buille

(Megan Brazil, *The International Educator*, 2 February 2017.) At the United Nations International School of Hanoi, teachers are trained to practice the “art and

science” of their roles through understanding student learning data in quarterly Learning Retreats. The author provides tips to help facilitate productive dialogue around student data.

Code Red: The Danger of Data-Driven Instruction

go.nmc.org/edule

(Susan Neuman, *Educational Leadership*, November 2016.) Researchers from New York University explore how data-driven instruction looks in nine public schools in New York City. Based on classroom observations and interviews with teachers and administrators, the team concluded that emphasis on data negatively affects students who need high-quality instruction to improve their literacy skills.

Commentary — The Learning Conundrum: How to Measure and Reform Children's Education in India?

go.nmc.org/scolin

(Vyjayanthi Sankar, *Reuters*, 20 March 2017.) An education expert from the Center for Science of Student Learning in Delhi provides four main pieces of advice for the Indian government as it adopts a milestone initiative to measure learning in primary schools nationally. She cautions that tests must be designed to measure whether students can apply the concepts to solve real problems, rather than promoting rote memorization.

Data Walls (Video)

<http://go.nmc.org/diffin>

(Mark Egger, Christine Lynch, DeLynn Hughes, *Teaching Channel*, accessed 6 July 2017.) Education leaders from Shaw Middle School in Washington describe the benefits they have experienced from tracking student progress using visible “data walls” and differentiating their instruction.

How Data Is Driving a Math Turnaround at Boston's English High

go.nmc.org/enhigh

(Max Larkin, *Edify*, 10 April 2017.) A high school once deemed among the worst performers in the state experiences a transformational change when instructors begin to meet students where they are. By tracking student progress and meeting their individual needs, the principal believes the school has been able to effectively tackle gaps in student achievement.

World Bank Says World Is Experiencing a “Learning Crisis” for School Leavers

go.nmc.org/wolban

(Sophie Edwards, *Devex*, 19 April 2017.) The 2018 World Development Report will focus on the “learning crisis” that is happening in low- and middle-income countries where school-age children are leaving school with inadequate literacy and numeracy levels. Creating metrics and systems of measurement to track student learning will be explored in depth as a potential solution for this global problem.

Redesigning Learning Spaces

Mid-Term Trend: Driving technology adoption in K–12 education for the next three to five years



As conventional teaching models evolve and emerging technologies gain a solid foothold in classrooms worldwide, formal learning environments require an upgrade to reflect the 21st-century practices taking place within them. Education has traditionally relied on teacher-centric approaches where lectures were the main source for knowledge transference. Today, student-centric pedagogies are being embraced to better prepare learners for the future workforce, and new approaches to classroom design are supporting this shift.⁷⁵ Active learning spaces have the characteristics of being mobile, flexible, varied, and connected — they value tables, stations, and hubs over rigid structures. Additionally, innovative thinking in architecture and space planning is influencing the sustainable design and construction of new school infrastructures that can significantly improve learning by enhancing student well-being with an eye to conserving energy.⁷⁶

Overview

Schools around the world are rethinking how to use existing spaces, while emerging schools are incorporating designs where new forms of teaching, learning, and technology are taken into consideration.⁷⁷ New learning spaces no longer look like traditional classrooms with rows of forward-facing seating arranged in a rectangle — instead, they are modular and arranged in ways that support the learning that is desired. Thought leaders in the field agree that these new learning spaces must move from an industrial model to one that is more student centered. Their design should be maximized to support more collaboration, self-directed learning, active learning, and inquiry and creation.⁷⁸ Australian researchers, for example, are using metaphors to classify and better understand contemporary learning spaces — these include “campfire” for learners to face a teacher for traditional instruction, “watering hole” where students can have informal discussions, “cave” for independent and reflective work, and “mountaintop” for presenting work to demonstrate understanding.⁷⁹

The US Census Bureau estimates that \$41 billion was spent on new K–12 school construction and renovations in 2016, with remodeling outnumbering new buildings by two-to-one. Popular among the new spaces is the notion of flexibility. Open classroom designs with

movable furniture to offer more seating options, floating floor systems to make technology integration easier and adjustments less costly, and tech-free zones to support deeper concentration are just some of the new features of these environments.⁸⁰ Reducing water and energy usage and greenhouse gases are also important in these new spaces. For example, in Ontario, Canada, the government is setting aside \$16 billion for school construction and renovation to ensure its schools are more energy efficient.⁸¹

New pedagogies that leverage technology are impacting the design of learning spaces. Blended learning includes a variety of activities such as small-group work, hands-on activities, and individual work on computing devices. Intrinsic Schools is the first high school in Chicago specifically built for blended learning. Instead of renovating an existing school building, designers repurposed an unused lumberyard with a large footprint and tall ceilings. The space allowed designers to create tandem pods for each grade level, one dedicated to arts and humanities and another to STEM subjects. Students can move about with their laptops at different parts of the day and they are monitored in real time via the school’s wireless network.⁸² School libraries are also at the nexus for rethinking learning spaces because they are the largest yet often least-utilized spaces. Experiential learning through robotics, 3D printing, and virtual reality often occurs in the library media centers, requiring the purging of some reference items to create more room for these activities.⁸³

Implications for Policy, Leadership, or Practice

Across the globe, schools are attempting to become sustainable and accessible communities. For example, the Leadership in Energy and Environmental Design (LEED) program provides a rating system devised by the US Green Building Council to evaluate the environmental performance of a building and encourage sustainable design.⁸⁴ Similar to LEED is the Green Globe rating system developed in Canada and used now in the US, which can be integrated into schools at the policy level. Both systems provide scales for rating the sustainability of new and existing buildings, addressing factors such as energy, water, emissions, project management, indoor environment, and materials and resources.⁸⁵ To

be recognized as a Green school, LEED schools must use the building to teach about sustainability and create a curriculum for teaching environmental education; for example, the Virginia Beach School Division teaches elementary students how the built environment and earth systems work together, helping to provide awareness about how the school building is reducing pollution runoff to the Chesapeake Bay.⁸⁶

Leading planners and architects are aware of how a learning environment looks, feels, and responds to the needs of the learners and are developing frameworks for schools to follow. The architecture firm Fielding Nair International, for example, has developed four criteria for educational spaces: welcoming, versatile, supportive of varying and specific learning activities, and conveying positive images about activities and behavior.⁸⁷ In New Zealand, the federal government shares the OECD's holistic viewpoint toward the four key areas of learning environments — resources, educators, learners, and content — and has taken the lead in generating resources to assist schools in planning and implementation. They believe these environments should be learner focused and emphasize learner outcomes. Their Innovative Learning Environments website includes school perspectives, teaching and learning approaches, and ways in which infrastructure can support innovative learning.⁸⁸

Exemplars of this trend can be seen worldwide, such as Poway's Design39 Campus near San Diego, California, which is a student-centered, design-focused, and project-based school. Every space at Design39 provides a learning opportunity — learners in the hallway, at the base of the steps, or in a flexible classroom are active investigators working collaboratively or on personal projects using design thinking infused with easily accessible technology.⁸⁹ At the International School of Kazan, Russia, both the exterior and interior spaces are welcoming, using bright colors that reflect the Tatar traditions of the region. The design is versatile, allowing for redesign at any time in the future as learning models and student needs evolve. In addition, there are various sizes of "learning studios" grouped around "learning commons" that provide for project-based learning outside the classroom, greater access to digital technology, and areas for research, small-group work, presentations, and social interaction.⁹⁰

For Further Reading

The following resources are recommended for those who wish to learn more about redesigning learning spaces:

5 Evidence-Backed Examples of Biophilic Design for Schools

go.nmc.org/biop

(Koru Architects, accessed 28 July 2017.) As schools begin to engage with sustainability, they can look to new research about the benefits of biophilic design, in which architectural and interior design incorporates or mimics nature. Studies have shown the positive psychological and physiological effects of these spaces.

Architecture's Pivotal Role in the Future of K–12 Learning

go.nmc.org/11sec

(Catherine Lange, Ed Surge, 11 July 2016.) A majority of schools are decades old and are built for chalk-and-talk modalities. This post describes the new directions in sustainable use of lighting, power, and energy that can provide opportunities for innovation.

Designing Engaging Learning Spaces

go.nmc.org/desen

(Michelle Mano, ISTE, 1 January 2016.) A columnist outlines key elements for teachers to consider in the design or redesign of a physical learning space, including layout, color, and walls. The author also shows how virtual learning spaces like display screen and audio systems are integral to learning.

Every Space Is a Learning Space

go.nmc.org/evspace

(Toh Wen Li, *Straits Times*, 6 March 2017.) Singapore's Ministry of Education's Flexible School Infrastructure Programme helps support and fund the construction of innovative learning environments. An eco-aquarium classroom, for example, helps students learn about ecology more authentically.

Future Classroom Lab — Learning Zones

go.nmc.org/fcl

(European Schoolnet, 2016.) This European report identifies examples of flexible furniture, different seating configurations, access to mobile digital tools, and the need for both formal and informal learning areas based on individual learning goals.

K–12 Blueprint — Active Learning Spaces

go.nmc.org/k12b

(Clarity Innovations, accessed 14 July 2017.) The edtech consultants Clarity Innovations share a toolkit with floor plans, success stories, videos, and other resources that address how schools can design learning spaces based on active learning.

Coding as a Literacy

Short-Term Trend: Driving technology adoption in K–12 education for the next one to two years



Coding refers to a list of rules, written in one of numerous programming languages, that instructs a computer to do what a user wants it to do: perform a sequence of instructions, repeat a sequence of instructions a prescribed number of times, and test whether a sequence was performed correctly.⁹¹ Many educators believe that coding helps children to understand how computers work, to communicate their thoughts through structure and logic, to think critically, and to be successful in the increasingly digital workplace.⁹² Code.org recently stated that computing occupations are among the fastest growing and best paying jobs in the US, and that there are currently 500,000 unfilled jobs in that sector.⁹³ To better prepare learners from a young age, an increasing number of school leaders and technologists are making the case for embedding coding into K–12 curricula.

Overview

Computer science remains one of the fastest growing industries across the world and preparing the future workforce is critical for economic success. Coding literacy is becoming increasingly necessary across all industries as fields including data analysis, marketing, web development, and more require some form of coding proficiency. At a minimum, non-tech-related fields require some coding knowledge to understand the tasks of other departments so that all employees can more effectively work with their colleagues.⁹⁴ The App Association states that the current demand for coding far outpaces supply in the US — nearly 250,000 jobs for software developers remain unfilled.⁹⁵ The World Economic Forum's *Future of Jobs* report states that the world is at the beginning of the Fourth Industrial Revolution, requiring new skill sets since 65% of children entering school today will work in jobs that currently do not exist. They predict that between 2015 and 2020, there will be a total gain of 2 million jobs in STEM-related fields.⁹⁶

Developing the future workforce is important, but coding literacy at its base level can also help students build transferable skills. Using tools such as the programming language Scratch, students have an avenue for innovation, invention, and creative expression. It is a vehicle for combining a range of subjects because it requires the integration of verbal and mathematical

skills. Coding also builds problem-solving skills, encourages collaboration, and can engage students who may otherwise be uninterested in their learning through its link to gaming, robotics, and animation.⁹⁷ Computer coding is also highly regarded in that it is a universal language that enables users to communicate across borders. Coding isn't limited to the higher grades — children as young as four years old can learn basic concepts — and its benefits will continue to grow.⁹⁸

After the notable initiatives Hour of Code⁹⁹ and Computer Science for All¹⁰⁰ in the US, a growing number of informal learning opportunities are working to globally scale this short-term trend. Two projects in Africa are intended to teach hundreds of thousands of children how to code. BraceKids is a software writing program using the simplistic coding language BraceScript to develop future software engineers.¹⁰¹ Similarly, Africa Code Week provided live and face-to-face workshops to children in 30 countries, training them in programming languages.¹⁰² The Refugee Code Week initiative, launched in 2016, provided coding workshops and boot camps to more than 10,000 refugees from the Middle East to address high unemployment. In the UK, the Welsh government has invested £1.3 million to set up after-school clubs to teach computer coding, noting that an estimated 100,000 new coding jobs will be needed by 2020.¹⁰³

Implications for Policy, Leadership, or Practice

Due to the significant role that computer science is playing in bolstering national economies and global competitiveness, governments are increasingly developing policies that support coding curricula. As a component of their digital literacies curriculum, the Australian government has placed digital technologies as a new learning area under the Australian curriculum. Students from foundation to year 10 will learn coding to build their information and communication technology (ICT) competence.¹⁰⁴ In Ireland, the National Council on Curriculum and Assessment is designing a new math curriculum that will teach coding in primary schools. The goal is to ensure that Irish children develop creative thinking skills that form the foundation of computer science and coding.¹⁰⁵ Instead of merely adding coding to the curriculum, the state of Florida made the bold decision to allow computer coding to fulfill high school

foreign language credits — becoming the first state in the US to do so.¹⁰⁶

Advancing this short-term trend requires leaders to think deeply about how to boost diversity in tech so that women and minorities can reap the benefits of coding. Rails Girls, a nonprofit started in Finland, has been working for years to provide tools and community support to women to encourage the use of technology. The organization provides training in sketching, prototyping, and basic programming around the world, including in Slovakia, Brazil, and Japan.¹⁰⁷ In New York City, nearly 70% of the city's overall student body is black and Hispanic, but only 10% of that demographic attend elite technical high schools that offer quality computer science courses. All Star Code is a nonprofit created to address this challenge, introducing minority youth to free summer computing courses. In 2016, they received a \$250,000 donation from AT&T to expand their summer classes and services.¹⁰⁸ More on the achievement gap is found later in the report.

Many nations around the world are formally integrating coding classes into their curriculum. Under new national curriculum standards in the UK, coding lessons break down into three distinct stages: Key Stage 1 introduces the concept of algorithms, illustrated through the idea of recipes, followed by creating and debugging simple programs; Key Stage 2 covers concepts including variables and sequence, selection, and repetition in programs; and Key Stage 3 provides training in Boolean logic, binary numbers, and how computer hardware and software work in tandem.¹⁰⁹ Finland and South Korea also have coding coursework embedded in their school systems. Finnish pupils learn to first create basic sequences of instructions, then code their own programs in a visual environment, followed by applying algorithmic thinking to simple programs. South Korea topped the International Telecommunication Union's ICT Development Index rankings in 2016 for the second consecutive year due to their high attention to coding in their national curriculum. Partnerships with industry are bolstering Korean learners' training; for example, I-scream is a digital media platform provided by Sigongmedia that offers customizable coding content for schools.¹¹⁰

For Further Reading

The following resources are recommended for those who wish to learn more about coding as a literacy:

24 Coding Programs Boosting Diversity in Tech

go.nmc.org/divtech

(Kadenze Blog, 15 October 2016.) While minorities and women continue to be underrepresented in the tech industry, this post highlights 24 international programs, such as Women Who Code, #YesWeCode, and We Can

Code It, that are addressing the disparity through a variety of approaches.

Best Coding Tools for High School

go.nmc.org/bestco

(Common Sense Education, accessed 13 July 2017.) This post lists tools that high school students can use to learn more about coding and how to write code. It includes both block-based programming such as Code.org and Scratch websites and text-based programming resources through CodeCombat and Construct 2 games.

Coding in the Armenian Classroom:

A Quiet Revolution

go.nmc.org/codarm

(Lilit Petrosyan, *The Armenian Weekly*, 17 November 2016.) A secondary school in Gargar, Armenia, served as a coding hub during the summer. Over nearly two weeks, children from grades two to five learned the foundations of coding through gaming and visual art elements using learning materials sourced from Code.org. The pilot project was a success and education leaders have plans to create more after-school coding opportunities.

Modern Literacy: Teaching Elementary Students

How to Code

go.nmc.org/codcomp

(Denizhan Pak, Roosevelt Institute, accessed 10 August 2017.) In Knox County School District, elementary students learn Boolean logic in first-grade math classes followed by programming-inspired games in second and third grades, before tackling more theoretical classes in Python in grades four and five.

Ottawa's Coding-Classes Promise Could Prove to Be a Real Bargain

go.nmc.org/ottcod

(Campbell Clark, *The Globe and Mail*, 14 June 2017.) This article ponders a new \$50 million initiative by the Canadian government to teach children computer programming. The program will invest in nonprofit-centered coding instructors and classes with the goal of reaching 500,000 children and providing professional development to teachers.

Trends in the State of Computer Science in U.S. K–12 Schools

go.nmc.org/statecom

(Google Inc. and Gallup Inc., accessed 13 July 2017.) While the importance of building coding literacy for future success is well noted, its integration in schools remains uneven. This report highlights that only 60% of schools surveyed offered at least one computer science course, underscoring the need for more urgency in the embedding of coding instruction in schools.

Rise of STEAM Learning

Short-Term Trend: Driving technology adoption in K–12 education for the next one to two years



In recent years, there has been a growing emphasis on developing stronger science, technology, engineering, and mathematics (STEM) curricula and programs; these disciplines are widely viewed as the means to boost innovation and bolster national economies. In response to the focus on STEM learning, many educators are advocating that integrating the arts, design, and humanities into STEM curricula is essential to build interpretive and creative skills. This notion has fostered the STEAM learning movement, in which the A stands for “art+.” Engaging students in a multi- and interdisciplinary learning context breaks down barriers that have traditionally existed between different classes and subjects and offers learners opportunities to make new connections. Educators are working together across disciplines to develop integrative projects and goals that give students perspective on how a wide variety of knowledge and skill sets tie into each other in the real world.¹¹¹

Overview

STEAM, multidisciplinary, cross-disciplinary, and interdisciplinary learning are terms used interchangeably with the common thread of placing school subjects into real-world contexts. Students start with a holistic topic and through their own inquiry explore and share knowledge, construct answers to questions, and creatively design solutions to problems.¹¹² Organizations such as LevelUp Village are encouraging cross-cultural learning through STEAM curricula by connecting students with peers in other countries.¹¹³ For example, high school students in New Orleans partnered with middle school students at Banjul American Embassy School in Gambia, West Africa, to brainstorm solutions to global climate change and design a website presenting their findings. The project gave students hands-on experience in creating meaningful change on a global scale. Not only did they build confidence using HTML, CSS, and JavaScript, they also engaged in the scientific subject matter through creativity and empathy.¹¹⁴

STEAM programming that incorporates the arts in other subjects is invigorating schools to value the learning process itself and leave room for more flexible outcomes as students take initiative, embrace trial and error, and express their knowledge in new ways. Both the creative process and scientific method begin with curiosity and

inquiry and require inventive thinking, experimentation, and multiple revisions.¹¹⁵ Perry Elementary in California discovered that launching an afterschool STEAM program to target at-risk youth allowed students to excel as they were presented with open-ended problems that piqued their curiosity and built confidence in their learning abilities. After witnessing the after-school program’s success, the school has held weekly staff meetings that allow educators to collaborate and plan cooperative interdisciplinary projects across all curricula.¹¹⁶

The integration of dance, drama, and the visual arts into subjects like math and science can further help students engage with subjects in new ways. For example, the Wolf Trap Institute in Virginia pairs art teachers with early-childhood educators to develop math lessons; a recent study by the American Institutes for Research found that students in classes from Wolf Trap-trained teachers performed better on math assessments than their peers in classes taught by educators not in the program. The teachers expressed that arts integration allowed the students to experience more perspectives on topics being covered. For instance, when students acted out a math equation by creating a story out of it, they better understood the measurements.¹¹⁷ Students can also strengthen vital skills that affect their ability to learn across subjects through artistic pursuits like music. Researchers have found that learning to play an instrument involves developing habits that promote executive functioning skills (cognitive processes that include problem-solving, goal setting, and flexible thinking).¹¹⁸

Implications for Policy, Leadership, or Practice

Finland has set a precedent in prioritizing interdisciplinary topics in its core curriculum for basic education through what is termed “phenomenon-based learning.”¹¹⁹ Students begin with cross-disciplinary topics such as the European Union or media and technology, pose related questions or problems, and then work in teams to construct answers by pulling knowledge from a number of disciplines.¹²⁰ Studying the human body, for example, may involve biology, psychology, health, and drawing visual representations.¹²¹ Individual schools can also develop their own policies that prioritize STEAM learning by providing opportunities for educators to

work together in planning integrated curriculum and projects. The St. Michael School of Clayton in Missouri engages the entire school in the same overarching topics through multidisciplinary research projects. Students participate in authentic experiences that connect different academic subjects while collaborating and expressing themselves through speech, art, music, and writing.¹²²

Efforts like the EuroSTEAM project are working to develop STEAM teachers by providing cooperatively developed resources and open tools as well as face-to-face training opportunities, helping educators promote creativity across all subjects.¹²³ The Australian Curriculum Symposium recently brought together educators, curriculum leaders, and stakeholders to discuss the intersections of STEM, STEAM, and the humanities and social sciences, in order to develop and integrate cross-curricular learning opportunities; workshop topics included new school-museum learning and teaching creatively.¹²⁴ In another example, seven curriculum directors from the Al Kifah Academy of Hofuf in Saudi Arabia participated in STEAM training to map out internationally accepted education standards and skills that aligned with their goals; they developed projects that encompassed the cross-disciplinary intersections between those standards and skills.¹²⁵

Targeted research, planning, and collaboration with university and industry partners are resulting in successful STEAM programs. Researchers from the University of Technology Sydney are working with students and educators from four high schools to co-design a project-based learning program called STEAMPunk girls. The program encourages girls to learn by doing, as they experiment and create while learning from female role models in STEAM industries.¹²⁶ Chinese International School in Hong Kong collaborates with MIT in Boston to run their CIS MIT STEAM Camp, empowering students to solve real-world challenges in areas including energy, education, and health.¹²⁷ Similarly, the Jordan Educational Initiative works with local schools to encourage students to think critically, using cross-disciplinary knowledge to solve real-life problems. The program provides software and tools that aid learner experimentation, including LEGO Machines, App Inventor, Microsoft Small Basic, Oracle Alice, and BrainPop, enabling students to apply inquiry-based learning toward creative projects and solutions.¹²⁸

For Further Reading

The following resources are recommended for those who wish to learn more about the rise of STEAM learning:

Building STEAM Skills with Hands-On Activity Collections

go.nmc.org/hand

(Daren Milligan, Smithsonian Learning Lab, 28 March 2017.) A designer for the Smithsonian Center for Learning and Digital Access created open activity collections that combine Smithsonian digital resources with hands on-practice to develop STEAM skills.

Building STEAM: The Value of the Arts

go.nmc.org/valu

(Stephen P. Johnson, Azusa Pacific University, 5 December 2016.) Azusa Pacific University in California has partnered with the Instituto Baccarelli in São Paulo, Brazil, to send students from the College of Music and Arts to teach and learn in São Paulo, using the arts as a common entry point to build lifelong habits and problem-solving skills.

Crayola Launches CreatED — PD for Educators with Focus on Arts

go.nmc.org/cray

(Richard Chang, *THE Journal*, 2 July 2017.) The crayon and coloring company Crayola has launched creatED, a professional development program to coach teachers on project- and inquiry-based learning strategies that leverage art as a vehicle to teach a variety of subjects.

New Class Brings Math, Manufacturing to Life

go.nmc.org/tolife

(Aaron Weinberg, *Pioneer News Group*, 19 June 2017.) Sedro-Woolley High School in Washington recently began offering an AMPED (algebra, manufacturing, process, entrepreneurship and design) class. In the class, students are engaging in STEAM subjects to invent, design, and fabricate new ideas and products.

Perform

go.nmc.org/perf

(Perform, accessed 26 July 2017.) The Perform project is investigating how the performing arts can nurture young peoples' engagement with STEM subjects and research while helping them build social and civic competencies and values in schools across France, Spain, and the UK.

The STEAM Journal

go.nmc.org/steamjour

(Claremont.edu, accessed 26 July 2017.) Claremont Colleges publishes a transdisciplinary, international, theory-practice, peer-reviewed, academic, open access, online STEAM journal that focuses on the intersection of the sciences and the arts.

Significant Challenges Impeding Technology Adoption in K–12 Education

The six challenges described on the following pages were selected by the project's expert panel in a series of Delphi-based cycles of discussion, refinement, and voting; the expert panel was in consensus that each is very likely to impede the adoption of one or more new technologies if unresolved. A complete record of the discussions and related materials were captured in the online work site used by the expert panel and archived at go.nmc.org/2017-k12-challenges.

Because not all challenges are of the same scope, the discussions here are sorted into three categories defined by the nature of the challenge. The Horizon Project defines solvable challenges as those that we both understand and know how to solve; difficult challenges are ones that are more or less well understood but for which solutions remain elusive; and wicked challenges, the most difficult, are categorized as complex to even define, and thus require additional data and insights before solutions will be possible. Once the list of challenges was identified, the challenges were examined through three meta-expressions: their implications for policy, leadership, and practice. Below are summaries of the six significant challenges that will be explored in more depth in this section, with citations and resources included.

Solvable Challenges: Those that we understand and know how to solve

Authentic Learning Experiences. Authentic learning experiences bring students in touch with real-world problems and work situations. The term “authentic learning” is seen as an umbrella for several important pedagogical strategies that have great potential to immerse learners in environments where they can gain lifelong learning skills.¹²⁹ Although these types of learning environments are still not pervasive, an increasing number of schools have begun bridging the gap between academic knowledge and concrete applications by establishing relationships with the broader community. Through active partnerships with local organizations, learners can experience the future that awaits them outside school and develop essential skills that benefit them beyond the classroom.¹³⁰ From school internship programs, community-based projects, apprenticeships, career academies, and more,¹³¹ schools are deploying these solutions to combat this challenge.

Many of these successful implementations of authentic learning are technology-driven initiatives, in part due to the growing need to digitally upskill students.

Improving Digital Literacy. To use technology productively and enable intuitive adaptation to new contexts and co-creation of content with others, students must acquire a deep understanding of the digital environment.¹³² Schools are charged with developing students' digital citizenship, ensuring mastery of responsible and appropriate technology use, including online etiquette and digital rights and responsibilities in blended and online learning settings.¹³³ Due to the multitude of elements comprising digital literacy, it is a challenge for schools to implement a comprehensive and cohesive approach to embedding it in curricula. Frameworks are helping schools identify areas in which students need support to build their confidence, autonomy, and capacity to contribute to an evolving digital landscape. However, creating digitally literate citizens requires they have access to the internet and related technologies, which is an interrelated challenge that is deterring many schools from resolution.

Difficult Challenges: Those that we understand but for which solutions are elusive

Rethinking the Roles of Teachers. Teachers are increasingly expected to be adept at a variety of technology-based and other approaches for content delivery, learner support, and assessment. In the technology-enabled classroom, educators are moving beyond dispensing information and assessing students' knowledge, which are tasks that can be increasingly outsourced to machines. Teachers now address social and emotional factors affecting student learning, mentor students, model responsible global citizenship, and motivate students to adopt lifelong learning habits. These evolving expectations are changing the ways teachers engage in their own continuing professional development, much of which involves collaboration with other educators both inside and outside their schools and the use of new digital tools and resources. Pre-service teacher training programs are also challenged to equip educators with digital and social-emotional competencies, such as the ability to analyze and use student data, amid other professional requirements to ensure classroom readiness.

Teaching Computational Thinking. Teaching computational thinking, synonymous with complex thinking, is still in its ascendancy as definitions continue to evolve and as curricula are built, and it is requiring the development of new forms of pre-service and in-service teacher training to be adequately taught in schools. To succeed in the 21st century, it is essential for young people to learn how to be computational thinkers, defined by the International Society for Technology in Education as the ability for students to “develop and employ strategies for understanding and solving problems in ways that leverage the power of technological methods to develop and test solutions.”¹³⁴ A method of formalized problem-solving, computational thinking is a strategy that leverages the power of computers through collecting data, breaking it into smaller parts, and recognizing patterns. While designing and implementing code is one way to solve problems in our increasingly digital world, it is only one approach that computational thinkers can employ.¹³⁵

Wicked Challenges: Those that are complex to even define, much less address

The Achievement Gap. The achievement gap refers to an observed disparity in academic performance among student groups, especially as defined by socioeconomic status, race, ethnicity, or gender.¹³⁶ This challenge also encompasses geographic inequities in student achievement as well as disparate access to educational opportunities inside and outside school.¹³⁷ Within the classroom, learners can be exposed to behaviors such as biases and negative stereotyping that influence their achievement and prevent them from realizing their potential. As researchers illuminate patterns of lower performances within student populations, educators and leaders will be better equipped to understand contributing factors and design targeted intervention methods and engagement strategies that help close the gaps. Additionally, children in countries experiencing civil unrest continue to encounter obstacles to accessing education. Global concerted action by philanthropic and multinational organizations will be necessary to raise awareness and identify promising solutions.¹³⁸

Sustaining Innovation through Leadership Changes. Multiple resources, including funding, time, and personnel, are required to effectively implement the innovative teaching and learning pedagogies highlighted throughout this report. Disruption to any one of these resources leaves organizations scrambling to fill the missing pieces. The process of preparing for the unknown is not always well defined, nor is it currently the norm in K–12 schools. Unfortunately, leadership vacancies or transitions can result in project delays or hinder the development and growth of programs designed to effectively meet student needs.

Turnover can also render promising initiatives without a driver, especially if a clear innovation strategy is not implemented to propel sustainable change and if other participants do not feel a sense of ownership over the program. Schools must identify successful strategies for making continued progress on promising innovations in the face of transitioning authority or run the risk of stalling initiatives that could lead to increased student success.¹³⁹

The following pages provide a discussion of each of the challenges highlighted by this year’s expert panel, which includes an overview of the challenge, its implications, and a set of curated recommendations for further reading on the topic.

Authentic Learning Experiences

Solvable Challenge: Those that we understand and know how to solve



Authentic learning experiences bring students in touch with real-world problems and work situations. The term “authentic learning” is seen as an umbrella for several important pedagogical strategies that have great potential to immerse learners in environments where they can gain lifelong learning skills.¹⁴⁰ Although these types of learning environments are still not pervasive, an increasing number of schools have begun bridging the gap between academic knowledge and concrete applications by establishing relationships with the broader community. Through active partnerships with local organizations, learners can experience the future that awaits them outside school and develop essential skills that benefit them beyond the classroom.¹⁴¹ From school internship programs, community-based projects, apprenticeships, career academies, and more,¹⁴² schools are deploying these solutions to combat this challenge. Many of these successful implementations of authentic learning are technology-driven initiatives, in part due to the growing need to digitally upskill students.

Overview

Authentic learning leverages students’ experiences, both those that are familiar and those still novel, to incorporate real-world skills into the learning process. Rather than traditional lectures in which the teacher acts as a “depositor” of knowledge, this pedagogy focuses on learning by doing, placing the student at the center of instruction.¹⁴³ Many consider authentic learning as the intersection of experiential learning¹⁴⁴ and real-world experiences, where students are actively involved in the learning process and find ways to relate the topic and skills back to their own lives. A recent study found that seventh graders in Turkey who engaged in technology-driven authentic learning experiences, such as publishing a newspaper and filming a short movie, exhibited an increase in satisfaction while completing their studies, leading to more engaged and self-directed learning.¹⁴⁵

While evidence indicates that authentic learning is a strategy that can improve learner outcomes, this pedagogy remains a challenge due to, in part, the lack of definition around the term “authentic.” One critic questions the use of the phrase “real-world” as

a synonym for authenticity, arguing that individual predisposition can place a bias on the understanding of this term. The focus, and challenge, of this pedagogy is to create “their-world” experiences for learners that are both relevant and timely to students’ lives.¹⁴⁶ Another barrier to its adoption is the systematic belief that failure is a less than favorable outcome — by contrast, authentic learning incorporates failure as a distinct part of the learning process. Some primary school teachers have noted that when students feel empowered to make mistakes, they are less likely to shy away from learning from their misunderstandings.¹⁴⁷ This is an important facet of the challenge that must be addressed, as failure is inevitable both inside and outside the classroom.

Although there are barriers to its widespread adoption, the many success stories of this pedagogy categorize it as a solvable challenge. For example, students at Kahibah Public School, an Australian primary school, are helping rebuild the dilapidated playground. This opportunity to involve students in a school project leveraged project management, collaboration, and problem-solving skills into the curriculum.¹⁴⁸ Similarly, a technology integration coordinator from Westwood Regional School District in New Jersey recommends using a combination of strategies, including podcast production and online publishing, to help students understand the concept of digital citizenship.¹⁴⁹ Authentic learning can also allow students to relate difficult concepts to their own lives.¹⁵⁰ In the US, NASA is working with K–12 students and faculty to bring insight into future careers STEM education offers. The goal of the program is to bolster students’ interest about STEM subjects and to offer authentic role models.¹⁵¹

Implications for Policy, Leadership, or Practice

The European Commission recognizes the importance of upskilling its citizens to meet the ever-growing demands of technological services in the workforce and is using K–12 education as a notable pathway, identifying projects that should be replicated throughout Europe. Samsung’s Digi Pass is a five-month digital and social competencies training program aimed at primary school children in Estonia; participating students develop real-world digital projects, such as apps.¹⁵² In schools across the US, authentic learning

experiences are being integrated into classrooms at a policy level. For example, for 2018 the Roaring Fork School District in Colorado has updated its graduation requirements to incorporate a capstone project. The goal is to develop students' critical thinking skills while also involving community outreach in efforts to scale real change initiated by students.¹⁵³

Enabling successful authentic learning experiences inside the classroom requires teachers to update their curricula and integrate relevant tools. Recognizing the need for leadership in this area, the University of South Australia's Connect program is offering professional development for secondary school teachers across the country that helps them develop engaging projects that incorporate tools like 3D printing and electronic games while exposing them to career choices relevant to their studies.¹⁵⁴ The University of Edinburgh is pioneering a new research initiative that focuses on elevating the student voice in schools across Scotland. One primary goal of the project is to understand what types of "authentic and meaningful participation" for students will lead to increased engagement within their learning process.¹⁵⁵ Recognizing the benefits of exposing students to future opportunities, colleges are providing campus internships — for example, the University of Delaware College of Engineering program hired junior and senior high schoolers to participate in their 2017 Summer Intern program.¹⁵⁶

As previously stated, authentic learning is categorized as a solvable challenge in part due to the exemplars who implemented this pedagogy within their classroom. Founded in August 2016, Millennium School is an independent middle school start-up in San Francisco that fosters student-centered learning environments. Two of the key components are experiential learning and real-world design, which incorporate community-based projects. For example, each student is assigned an "occupation," which is a role that can range from cooking lunch to managing a budget, and building that skill helps them contribute to the community.¹⁵⁷ Another authentic learning project stems from New Zealand's Road Safety Week, a community-based program that aims to increase safe driving conditions. A local school is leveraging this opportunity to contextualize learning by using resources from both inside the classroom and the community at large. One project will involve statistics students in investigating transport issues, like wet road conditions and the impact of texting while driving.¹⁵⁸

For Further Reading

The following resources are recommended for those who wish to learn more about authentic learning experiences:

5 Barriers to More Authentic Teaching and Learning

go.nmc.org/auth

(Drew Perkins, TeachThought, accessed 28 July 2017.) This article highlights five barriers schools need to address before teaching and learning practices can include more project-based, authentic experiences; included are rigid curricula, classroom silos, hard-to-change policy, and test standardization.

An Authentic Learning Experience

go.nmc.org/news

(Emily Chan, The Start, 26 March 2017.) The Newspaper-in-Education (NiE) program promotes learning through a universal resource. Whether digital or paper, reading the news in a learning environment instills the importance of learning the English language and demonstrates the applicability of that knowledge in real life.

Education Experts and Private Sector Leaders Address the Workforce Readiness Gap in São Paulo State

go.nmc.org/ready

(Council of the Americas, 11 May 2017.) Experts gathered in São Paulo, Brazil, to support an initiative meant to match the skills needed by employers and those taught in skills-training institutions. Students can then gain authentic knowledge and experience that will make them invaluable in the workforce.

How Is Finland Building Schools of the Future?

go.nmc.org/finland

(Tan Wee Kwang, eGov Innovation, 31 January 2017.) Finland, a global leader in education, insists that rather than focusing on rote memorization skills and algorithms solved easily by computers, students should be developing higher thinking skills. Instilling new, collaborative teaching methods, like co-teaching, leads students to become active members of the learning process.

Learning through Internships: Connecting Students' Passions to the Real World

go.nmc.org/intern

(Edutopia, 16 August 2016). Through internships, students are given a chance to explore how their interests can develop into careers. Nashville Big Picture High School emphasizes internships so students gain confidence and leadership skills in a real-world setting that can then be carried to build their futures.

Why Failure Is Good for Success

go.nmc.org/fail

(Pauline Estrem, *Success*, 25 August 2016.) An important, yet overlooked, facet of authentic learning is building in failure as lessons for success. The business sector has begun embracing this notion by hiring employees who have successfully overcome failures.

Improving Digital Literacy

Solvable Challenge: Those that we understand and know how to solve



To use technology productively and enable intuitive adaptation to new contexts and co-creation of content with others, students must acquire a deep understanding of the digital environment.¹⁵⁹ Schools are charged with developing students' digital citizenship, ensuring mastery of responsible and appropriate technology use, including online etiquette and digital rights and responsibilities in blended and online learning settings.¹⁶⁰ Due to the multitude of elements comprising digital literacy, it is a challenge for schools to implement a comprehensive and cohesive approach to embedding it in curricula. Frameworks are helping schools identify areas in which students need support to build their confidence, autonomy, and capacity to contribute to an evolving digital landscape. However, creating digitally literate citizens requires they have access to the internet and related technologies, which is an interrelated challenge that is deterring many schools from resolution.

Overview

Despite years of modern students being referred to as “digital natives,”¹⁶¹ a number of studies have shown there are gaps in the digital knowledge and skills of young people.^{162, 163} A recent study from Stanford researchers found that K–20 students in the US are unprepared to judge the credibility of news and information they come across in their daily lives: “despite their fluency with social media, many students are unaware of basic conventions for identifying verified digital information.”¹⁶⁴ Compounding this, students are now born into a complex environment in which every online post, comment, or tag is public and permanent and can be viewed and shared by a vast audience. In a Kaplan survey of 350 college admissions officers in the US, 35% admitted to checking the social media profiles of applicants. Harvard also rescinded offers to 10 prospective students recently because they posted offensive content to social media.¹⁶⁵

While defining and measuring digital literacy remains a challenge due to its multidimensional and evolving nature,¹⁶⁶ current digital literacy frameworks from educational research leaders including Jisc,¹⁶⁷ UNESCO,¹⁶⁸ and MediaSmarts¹⁶⁹ share consistencies. One mutual component is the importance of information

literacy, which refers to finding, assessing, and using digital content. Further, the common goal of these frameworks is to empower users to better communicate, create, and participate in civic life through building skills encompassed in digital literacy. Schools are challenged to provide students with opportunities to produce their own content, which allows learners to experience firsthand how knowledge is constructed and disseminated. Analytic skills are also increasingly in demand to conceptualize, organize, and synthesize data, which helps students understand and deal with complex social problems.¹⁷⁰ Digital literacy spans across subjects and grades, taking a school-wide effort to embed it in curricula. This can ensure that students are empowered to adapt in a quickly changing world.¹⁷¹

In working to bridge the current digital divide, internet access and digital literacy training should go hand in hand. For example, only 9% of rural India is connected to the internet,¹⁷² and as organizations and companies work to provide internet access, digital literacy must be a parallel priority. Samsung India has set a precedent through its Samsung Smart Class program, which provides classrooms with Wi-Fi connectivity and power backup while also training teachers to use an interactive Smartboard with laptops and tablets. Feedback from teachers and principals of the participating Jawahar Navodaya Vidyalaya schools indicates that the program increased students' attention in classrooms and improved their familiarity and comfort with technology.¹⁷³

Implications for Policy, Leadership, or Practice

Governments are charged with providing support for digital literacy in schools. The G20 Insights Platform, which offers policy proposals to G20 countries, believes that developing an indicator to measure the uptake of digital literacy across countries will better align the supply of digital literacy skills with economic demand. This would also entail adopting a standardized definition of digital literacy and producing a multidimensional digital literacy index.¹⁷⁴ Already taking strides to integrate digital literacy in schools and address access issues, the education minister in New Zealand announced a \$40 million package that will make digital fluency curriculum compulsory in schools — half the amount will go toward upskilling teachers, while another portion will support

a Digital Technology for All Equity Fund that allows students from disadvantaged backgrounds to access digital learning opportunities.¹⁷⁵

Taking a leadership role in furthering digital literacy, Education Scotland has developed a nationally available digital learning environment for educators, offering safe and secure cloud-based services for collaboration, social learning, co-creation, and web publishing.¹⁷⁶ Scotland is also working to facilitate partnerships between schools and employers through its Developing Young Workforce program to ensure that schools improve young people's understanding and readiness for employment through digital technology.¹⁷⁷ The University of Adelaide's Computer Science Education Research Group hopes to empower teachers as they integrate digital literacy by providing free courses and a National Lending Library that gives them access to digital equipment including kits for incorporating Beebot, Sphero, Makey-Makey, Little Bits, and Arduino.¹⁷⁸ US-based nonprofit Common Sense is another leader offering educators a K–12 digital citizenship program with grade-differentiated lesson plans and toolkits on topics including internet safety, privacy and security, information literacy, and copyright.¹⁷⁹

Community partners including libraries, higher education institutions, and companies are helping schools explore their potential to positively impact the digital environment. Bard High School Early College students recently worked with the City University of New York and the New York Public Library to research archival materials about their school's neighborhood and contribute their own historical accounts through online mixed media projects covering topics such as gentrification in the Lower East Side, the neighborhood's drug epidemic in the 1970s through 1990s, and Nuyorican poetry from the Puerto Rican diaspora.¹⁸⁰ Microsoft has partnered with the International Rescue Committee to offer basic digital literacy training through YouthSpark programs and to build up ICT capacity across three refugee camps in Thailand. The programs also develop the creative, analytical, and problem-solving skills of young refugees, enhancing their employability and chances of securing a job when they leave the camps.¹⁸¹

For Further Reading

The following resources are recommended for those who wish to learn more about improving digital literacy:

Digital Literacy at CCGS

go.nmc.org/ccgs

(Central Coast Grammar School, 2017.) At Central Coast Grammar School in New South Wales, teachers participate in workshops and ongoing support to integrate digital

literacy across the curriculum, and students work on projects making use of digital collaboration zones, a film studio, a professional recording studio, and more.

Education Overview: Digital Literacy Has to Encompass More Than Social Use

go.nmc.org/lite

(Kit Bradshaw, TCPalm, 19 June 2017.) This article discusses the importance of student digital literacy surpassing a social context. Student technology skills must be developed so that students can shift from consumers to creators in the digital world.

Feature of Child-Led Digital Learning

go.nmc.org/hello

(Projects for All, 2017.) Project Hello World provides access to quality digital education for all students — those in traditional schools and those in need of educational opportunities. Child-led digital education enables a brighter future for many students in need.

From Literacy to Fluency to Citizenship: Digital Citizenship in Education

go.nmc.org/netsa

(Netsafe, November 2016.) As education policy encourages the uptake of digital technology in schools, there is a need for dedicated and sustained support to keep digital learning environments safe and secure. Netsafe advocates principles to underpin how schools develop digital citizens who fluently combine skills, knowledge, and attitudes.

Stop, Drop & Roll through Digital Literacy

go.nmc.org/sdr

(Sherawn Reberry, Marita Diffenbaugh, Idaho Digital Learning, 11 August 2016.) Students are immersed in the digital world before entering school, and Idaho school leaders want to ensure that they are using their resources carefully. Through the “stop, drop, and roll” method, students learn how to thoughtfully and effectively navigate the web.

What Web Literacy Skills Are Missing from Learning Standards?

<http://go.nmc.org/wls>

(An-Me Chung, Medium Corporation, 10 February 2017.) Mozilla has assembled a set of standards for web literacy and 21st-century skills, while urging authors of other international literacy standards to align with their recommendations. Their web literacy map and open-source training curriculum can be adopted into the classroom context to support existing curriculum.

Rethinking the Roles of Teachers

Difficult Challenge: Those that we understand but for which solutions are elusive



Teachers are increasingly expected to be adept at a variety of technology-based and other approaches for content delivery, learner support, and assessment. In the technology-enabled classroom, educators are moving beyond dispensing information and assessing students' knowledge, which are tasks that can be increasingly outsourced to machines. Teachers now address social and emotional factors affecting student learning, mentor students, model responsible global citizenship, and motivate students to adopt lifelong learning habits. These evolving expectations are changing the ways teachers engage in their own continuing professional development, much of which involves collaboration with other educators and the use of new digital tools and resources. Pre-service teacher training programs are also challenged to equip educators with digital and social-emotional competencies, such as the ability to analyze and use student data, amid other professional requirements to ensure classroom readiness.

Overview

To embrace new roles, educators need up-to-date research on learning methods. Further, schools must have mechanisms in place for teachers to track progress and gather constructive feedback. Evidence from teachers who are implementing innovations in the classroom can feed into research and best practices that other colleagues can use to improve practice. For example, a recent letter to *The Guardian* signed by leading researchers in psychology and education describes studies on the concept of learning styles, which have consistently found weak to no evidence supporting the hypothesis that matching material in the appropriate format to an individual's learning style is effective.¹⁸² These findings on a popular teaching approach underscore the need for more research on learning to determine which models and methods are effective. Evidence is needed to provide a foundation for developing relevant training, ongoing development, and accurate teacher evaluation.¹⁸³

Certification policies and new school reforms also impede teachers' capacities to evolve.¹⁸⁴ Required state tests cause teachers to pour their resources into testing fees and materials rather than into desired professional development opportunities. For instance,

an unprecedented number of teachers in Florida are failing the state's teacher test. Some taking the new exam have excelled in university teaching programs and been recognized as exceptional teachers by their communities. However, they have found the state test to be disjointed from their actual experience of teaching, requiring additional energy to pass it.¹⁸⁵ Policymakers must work more closely with teachers to understand the hardships their reforms can place on teachers and adjust them. In Australia, educators are demanding the withdrawal of new syllabuses outlining mathematics curriculum changes proposed by the New South Wales Board of Studies due to their confusing language and directives.¹⁸⁶

Schools that encourage collaborative, cross-disciplinary working environments can help teachers more seamlessly embrace new roles by learning from one another. At the Summit Public Schools in California, teachers move between roles including guiding students through project-based curriculum and leveraging data to give them better insight into student progress. Each student is further paired with a teacher who mentors them multiple times a week in group settings and one-on-one. Simultaneously, teachers meet and collaborate in reviewing student data, sharing best practices, and co-designing appropriate interventions for struggling students.¹⁸⁷ Classrooms are shifting from teacher centered to student centered with the aid of games such as Minecraft or Community in Crisis, which puts students in decision-making roles while they navigate real-world crises.¹⁸⁸ Teachers implementing new games and software learn alongside students, which requires a degree of risk on the teacher's part as they try new methods and learn what works.¹⁸⁹

Implications for Policy, Leadership, or Practice

The World Economic Forum is encouraging stakeholders across the globe to establish enduring policies that provide teachers with better conditions for experimentation and growth. Recommendations for policymakers are to fund research advancing the development of technology related to social-emotional learning and to create more opportunities for educators to experiment with new technologies and contribute to associated standards and ratings processes.¹⁹⁰ A recent Learning Policy Institute report also recommends that US policymakers and administrators evaluate and

redesign the use of time and school schedules to build in more opportunities for educators to evolve their practices through collaboration in professional learning communities along with peer coaching and observation across classrooms. It recommends that states, districts, and schools regularly conduct needs assessments using data from staff surveys to identify areas of professional learning most needed and desired by educators.¹⁹¹

Rethinking the roles of teachers entails improving teacher training and professional development. While many classrooms are incorporating digital devices and differentiated instruction as part of a movement toward recognizing that learning is not fixed to a specific pace, place, or time, professional development is often still delivered in a one-size-fits-all format. However, the Bismarck Public Schools district in North Dakota is setting a precedent, recently bringing together 35 teachers across seven middle and high schools to create personalized professional development options that meet the varying needs of their teachers. They developed an asynchronous learning environment with interactive multimedia, online discussion forums, and self-paced learning modules leveraging automated feedback.¹⁹² Another example of rethinking professional development is at Kettle Moraine High School in Wisconsin, which has adopted micro-credentials. Their system allows teachers to take courses of their choosing, through outside nonprofits like Digital Promise, or individually proposed credentials, and it compensates them by adding to their base pay for completing each micro-credential.¹⁹³

Schools can also develop their own support infrastructure to provide time and space for teachers to experiment with new ideas and adjust to evolving technologies. A team of four teachers at Veromäki School in Finland is working to create communities of digital co-teaching across each school grade. The goals are to improve sharing and planning between teachers and help them adapt their design of learning experiences to meet the demands of the digital age.¹⁹⁴ A two-month project in Hong Kong recently trained educators using interactive seminars and discussions, blended learning, online multimedia study, role-playing, and self-evaluation to better understand and impart social-emotional competencies. After participants put their training into action to design and implement a new curriculum, they saw a statistically significant improvement in social competence and reduction in anxiety-withdrawal and anger-aggression in students.¹⁹⁵

For Further Reading

The following resources are recommended for those who wish to learn more about rethinking the roles of teachers:

Does the Word “Teacher” Still Describe What Educators Do in the Classroom?

go.nmc.org/wordteacher

(Jenny Abamu, *EdSurge*, 13 July 2017.) Expectations of teachers have changed with teaching practice at an accelerated pace due to technology. Teachers now need a more interdisciplinary skill set and understanding as they learn new tools and cater to students' interests and habits.

Is Your School Getting Professional Development Right?

go.nmc.org/pdright

(Kulvarn Atwal, *tes*, 10 July 2017.) A London teacher urges schools to prioritize staff learning experiences so that all staff see themselves as leaders and have time to engage in research and reflection on their practices.

Not Just Consensus: Collaborative Leadership in Teacher-Powered Schools

go.nmc.org/teachpow

(Lars Esdal, *education evolving*, 20 April 2017.) Teachers are taking on roles as designers and decision makers in their schools. This article covers three exemplar teachers who have structured ways to encourage collaborative leadership between teachers.

The Role of the Teacher in High-Quality PBL

go.nmc.org/pbltea

(Michelle Berkeley, *Getting Smart*, 20 April 2017.) Education leaders offer perspectives on how to invest in the development of project-based learning teachers as they take on new roles to facilitate a flexible and supportive environment for student growth.

To Attract Great Teachers, School Districts Must Improve Their Human Capital Systems

go.nmc.org/attr

(Annette Konoske-Graf et al., Center for American Progress, 22 December 2016.) The Center for American Progress urges schools to improve how they recruit, train, and pay their employees. It offers recommendations to help schools rethink their approach to human capital management based on best practices in other fields so that they can attract and retain excellent teachers and support their continuous growth.

To Reach the Students, Teach the Teachers

go.nmc.org/casel

(Kimberly Schonert-Reichl et al., CASEL, February 2017.) A team of researchers at the University of British Columbia recently studied state requirements for teacher certification related to social-emotional learning and in what ways higher education institutions prepare teachers to impart related skills. They found an urgent need to further understanding of social-emotional learning in pre-service teacher education, and they provide recommendations in this report.

Teaching Computational Thinking

Difficult Challenge: Those that we understand but for which solutions are elusive



T*eaching computational thinking, synonymous with complex thinking, is still in its ascendancy as definitions continue to evolve and curricula to be built, and it is requiring the development of new forms of pre-service and in-service teacher training to be adequately taught in schools. To succeed in the 21st century, it is essential for young people to learn how to be computational thinkers, defined by the International Society for Technology in Education as the ability for students to “develop and employ strategies for understanding and solving problems in ways that leverage the power of technological methods to develop and test solutions.”¹⁹⁶ A method of formalized problem-solving, computational thinking is a strategy that leverages the power of computers through collecting data, breaking it into smaller parts, and recognizing patterns. While designing and implementing code is one way to solve problems in our increasingly digital world, it is only one approach that computational thinkers can employ.¹⁹⁷*

Overview

The roots of computational thinking can be traced to algorithmic thinking of the 1950s and 1960s, where learners began solving problems by converting inputs to outputs, using algorithms to perform the conversions.¹⁹⁸ Contemporary interest in these related skills gained popularity in the mid-2000s as new, more accessible viewpoints on computational thinking began to emerge. In the March 2006 issue of *Communications of the ACM*, Jeanette Wing coined the term “computational thinking,” arguing that it is a fundamental skill in addition to reading, writing, and arithmetic for all to master, including those not interested in pursuing the computer sciences.¹⁹⁹ As the nature of work changes over the next decade, computational thinking skills will be increasingly in demand. Experts suggest that computational thinking will impact not only software developer and computer systems analyst jobs but also market research analyst and marketing specialist jobs, with double-digit increases in jobs expected by 2024.²⁰⁰

Since popularization of the term “computational thinking” in the US, a lot of work has been done in the international community, yet it is still regarded to be in its infancy, resulting in its placement as a difficult challenge. Outside the computer science fields, universally agreed-on definitions have yet to be established, and integration of this concept into teaching at all levels of education

is still lacking.²⁰¹ This is especially true in Ireland, where researchers have noted that the only related curriculum is a short course in coding.²⁰² The report *The Case for Improving U.S. Computer Science Education* by the Information Technology & Innovation Foundation underscores computational thinking’s nascence. Among their key findings are that only one-quarter of high schools offer computer science courses, and many of them focus primarily on computer use or coding; only 18% of Advanced Placement (AP) accredited schools offer a computer science AP exam, and access to computing courses is mostly found in affluent schools.²⁰³

Another facet of this challenge is that teachers are still not well prepared to integrate computational thinking into their curricula. Researchers believe that pre-service teacher education needs to incorporate more content, pedagogy, and instructional strategies to embed computational thinking in more meaningful ways. Compounding this challenge is that few teacher preparation programs offer training specifically for computer science teachers, let alone those working in other disciplines.²⁰⁴ However, there is hope for reaching in-service educators. In the Australian report *Improving the Computational Thinking Pedagogical Capabilities of School Teachers*, researchers investigated this challenge with regard to teacher preparedness and found that in-service teachers can quickly improve their basic knowledge of computational thinking content, pedagogy, and technology by engaging in professional development workshops.²⁰⁵

Implications for Policy, Leadership, or Practice

Policymakers are developing initiatives that place computational thinking at the forefront of education agendas. In January 2017, the Malaysian Ministry of Education, working with private industry, made computational thinking part of the new standard-based curriculum for primary and secondary education. Its goal is to mobilize youth to become makers of their own technology, whether apps, games, or other digital innovations.²⁰⁶ Starting in September 2018, Canada’s *Code-ifying the Curriculum* initiative will require each student in British Columbia to complete a basic coding module prior to finishing the ninth grade. The Ministry of Education views computational thinking as a core skill that will benefit students in all areas of study. While noted as a challenge, even kindergarten students can comprehend

the concept of computational thinking with regard to choosing how to dress for recess as quickly as possible — certain garments need to be put on in a specific order, teaching them simple algorithmic problem-solving.²⁰⁷

Leaders in this area are working to help educators overcome the challenge of teaching computational thinking. In the UK, Computing at School's *Computational Thinking: A Guide for Teachers* is being used to help primary and secondary educators develop a shared understanding of teaching computational thinking in schools. It includes a framework, describes pedagogical approaches, and offers guides for assessment.²⁰⁸ For resources that span the globe, Google's Exploring Computational Thinking collection provides a curated set of 130 resources including lesson plans, demonstrations, and programs aligned to international education standards, and an online course on how to integrate computational thinking across diverse subject areas.²⁰⁹ The Computer Science Education Research Group in Australia is also focused on providing professional development for educators in the digital technologies learning space. Their open online courses cover foundational computer science²¹⁰ and computational thinking at primary and secondary levels.

Innovative schools are already integrating computational thinking from pre-school up. In Singapore, computational thinking begins at the pre-school level, where the *School of Fish* curriculum, loaded onto tablets, provides interactive features with characters, games, and analog activities to help young learners approach problem-solving and creative thinking.²¹¹ At the Excel Public Charter School in the US, students engage in a multitude of computational thinking techniques to tackle ambiguous problems across the curriculum by persisting through challenges, engaging in experimentation, and then communicating results.²¹² In a sixth-grade social studies class at Excel Public Charter School, the Ancient Civilizations computer-based course allows students to apply computational thinking to the rise and fall of civilizations, by making choices about resources that affect the resilience of the community over time.²¹³

For Further Reading

The following resources are recommended for those who wish to learn more about teaching computational thinking:

Computational Thinking, 10 Years Later

go.nmc.org/10yron

(Jeanette Wing, *Microsoft Research Blog*, 23 March 2016.) Following her seminal article defining computational thinking 10 years ago, this author explores the impact on policy. Since then, the UK's Computing At School efforts have led to requiring computing in K–12 schools, while in the US, the Computer Science for All Initiative has trained nearly 10,000 educators.

The Computing Curriculum — Two Years On

go.nmc.org/2yron

(Hannah Oakman, *Educational Technology*, 21 August 2016.) After ICT was replaced with computing curriculum in English primary and secondary schools, resources and training have been insufficient. Execution has been lacking as well, as a panelist notes that 80% of courses focus on paper exams, whereas only 20% involve problem-solving with devices.

Developing Computational Thinking in Compulsory Education

go.nmc.org/devcomth

(Stefania Bocconi, Augusto Chiocciariello, Giuliana Dettori, et al., *Developing Computational Thinking in Compulsory Education*, 2016.) This policy report provides a comprehensive overview of computational thinking skills within the European schools context, exploring recent research results and the impact of grassroots initiatives at the policy level.

On the Program for K–12: Computational Thinking

go.nmc.org/k12ct

(Joyce Malyn-Smith, *Education Development Center*, 5 December 2016.) This author describes how technology can help all students extend their own thinking and solve complex problems. She provides an example of how a lesson on disease transmission can help students understand the progression of an infectious outbreak using computational thinking.

A Plan to Teach Every Child Computer Science

go.nmc.org/plantec

(Emily Deruy, *The Atlantic*, 19 October 2016.) This article highlights the uneven distribution of computer science training across the US, noting that only about 50% of seventh to twelfth graders have access to dedicated computer science classes. The author notes that several organizations are working to create adaptable frameworks to address inequities.

Programming ^ Algorithms = Computational Thinking (PACT)

go.nmc.org/pact

(Maynooth University, accessed 29 June 2017.) The PACT program is a university-led initiative that is developing frameworks for delivering freely available computational thinking resources focused on developing creative ideas and new ways of thinking across disciplines in Irish primary and secondary schools.

Teaching Computational Thinking Is the First Step to Bridging STEM Skills Gap

go.nmc.org/bridgap

(Meghan Bogardus Cortez, *Ed Tech Magazine*, 2 November 2016.) Formalized problem-solving is at the heart of computational thinking; one US educator explains how teachers from any subject area can develop lessons that highlight this type of thinking.

Achievement Gap

Wicked Challenge: Those that are complex to even define, much less address



The achievement gap refers to an observed disparity in academic performance among student groups, especially as defined by socioeconomic status, race, ethnicity, or gender.²¹⁴ This challenge also encompasses geographic inequities in student achievement as well as disparate access to educational opportunities inside and outside school.²¹⁵ Within the classroom, learners can be exposed to behaviors such as biases and negative stereotyping that influence their achievement and prevent them from realizing their potential. As researchers illuminate patterns of lower performances within student populations, educators and leaders will be better equipped to understand contributing factors and design targeted intervention methods and engagement strategies that help close the gaps. Additionally, children in countries experiencing civil unrest continue to encounter obstacles to accessing education. Global concerted action by philanthropic and multinational organizations will be necessary to raise awareness and identify promising solutions.²¹⁶

Overview

Research indicates that socioeconomic status (SES) and student success are linked in a variety of ways. In Kenya, where more than half of the country's inhabitants live below the poverty line, parents may be unable to afford children's learning materials or medication, which can foster absenteeism.²¹⁷ The Stanford Center for Education Policy Analysis (CEPA) reports that US schools with higher proportions of low-SES students face disparities that can impact learner achievement, such as low teacher retention and fewer Advanced Placement courses.²¹⁸ CEPA also found that some of the US's largest race-based achievement gaps occur in relatively prosperous towns; contributing elements may include hypercompetitive academic atmospheres, fewer educators of color, and peer stereotyping.²¹⁹ Researchers from Northwestern University found that as students encounter race-based prejudice, biological reactions (including increased levels of stress hormones and impaired sleep quality) could impact academic performance and learner motivations.²²⁰

Teacher biases and stereotyping can lead to different treatment in the classroom. Scholars from Vanderbilt University examined racial compositions of US gifted and talented programs and found that teachers were less likely to recommend students of color for advanced

instruction, even when those learners exhibited high standardized test scores.²²¹ Further, a study by the American Educational Research Association revealed that elementary school teachers recognized girls' achievements in mathematics as equivalent to boys' only when they also perceived the girls to be working harder and behaving better than the boys. The resulting impact on girls' self-perception of their abilities can contribute to gender gaps in STEM career fields.²²² Additionally, female students can face gender-specific obstacles to education: Sierra Leone's education ministry has banned pregnant girls from attending mainstream schools. While UNICEF offers alternative school programs for expecting mothers, learners must repeat the academic year upon their return to mainstream schools in order to advance.²²³

The UNESCO Institute for Statistics reports that ongoing crisis and armed conflict in 35 countries has resulted in an estimated 21.5 million young people not attending school.²²⁴ The Overseas Development Institute, a UK-based think tank, found that girls in conflict settings are 2.5 times more likely than boys to stop going to school.²²⁵ Students in areas of unrest who are able to continue their studies often encounter substandard conditions, such as one teacher assigned to 70 learners.²²⁶ To equalize education opportunities in developing countries and conflict zones, Google.org recently pledged \$50 million to nonprofits using scalable technologies. Supported organizations include War Child Holland, which has developed a game-based platform to deliver curricula to displaced refugee children,²²⁷ and Pratham Education Foundation, which is spreading a hybrid learning program across schools in India.²²⁸

Implications for Policy, Leadership, or Practice

Polymakers are implementing initiatives to increase equity in education. As part of the Scottish Attainment Challenge to lessen income-related performance gaps, Scotland's government will provide £120 million to help schools implement evidence-based interventions or hire additional staff to better serve learners. Funding is proportionally allocated to schools based on the number of enrolled students eligible for free lunch programs.²²⁹ In Texas, the Fort Worth Independent School District recently voted to enact a racial and ethnic equity policy to address educational practices that foster race-based achievement gaps. Tenets of the policy include holding

students of all backgrounds to identical academic standards, eliminating curtailed instructional time due to disciplinary issues, and incorporating cultural responsiveness as a factor in curriculum and pedagogy reviews. The district will allocate over \$1 million for employee training in service of this initiative.²³⁰

To address the achievement gap, leaders must facilitate dialogues to better understand contributing factors and encourage the spread of best practices. UNICEF has appointed a teenage Syrian refugee as a Goodwill Ambassador; her work will focus on increasing educational opportunities for girls and raising awareness of schooling disruptions caused by living with, or fleeing from, ongoing conflict. She has spoken out about issues preventing young people from attending school, including early marriage and child labor practices.²³¹ Educators from K–12 schools across Iowa shared expertise on meeting the needs of the state's at-risk student populations at Drake University's recent one-day conference, "Increasing School Success and Graduation Rates for All Students." Topics included flexible learning environments, project-based learning, improving student resiliency and mental health, and developing cultural competencies.²³²

Innovative approaches are bridging achievement gaps through targeted support. For example, the community school model provides low-SES students with access to services that help them meet basic health needs and improve their ability to pursue education. One successful implementation is Broome Street Charter Academy in New York, whose student population faces challenges including homelessness, incarcerated parents, and criminal arrests. The school is housed within the Door, a community center for at-risk teens: students can access counselors, attorneys, dentists, and career advisors. Broome Street has achieved an on-time graduation rate of 72.4%, trailing the city's average by just 0.2%.²³³ Education-focused community organizations can also increase opportunities. A Singapore nonprofit, 21C Girls, is reducing barriers to STEM fields for girls by developing their computational thinking skills through exploration of programming, robotics, and more. The organization recently hosted Fintech Camp, a weeklong boot camp where girls ages 12–18 built mobile apps. The group is also working with local cultural organizations to identify underserved students ages 8–15 to learn programming languages through Coding in the Community classes.²³⁴

For Further Reading

The following resources are recommended for those who wish to learn more about the achievement gap:

Creative Ways to Close the Achievement Gap

go.nmc.org/closegap

(Matthew Lynch, *The Edvocate*, 25 November 2016.) This article presents 10 US-based solutions in action that are

working to address the achievement gap. For example, year-round schools' modified calendar can result in improved academic performance for low-SES students who may lack resources to engage in continued learning opportunities during school breaks.

Mass Incarceration and Children's Outcomes

go.nmc.org/incargap

(Leila Morsy and Richard Rothstein, *Economic Policy Institute*, 15 December 2016.) The authors examine race-based achievement gaps in the United States in relation to the incarceration of persons of color. When controlling for other factors such as SES, children of incarcerated parents are more likely to suffer developmental challenges and have higher dropout rates.

A New Generation of All-Girls Schools

go.nmc.org/girlschool

(Audrey Cleo Yap, *The Atlantic*, 14 October 2016.) As single-sex classes and schools crop up in response to the STEM gender achievement gap, some critics argue that more significant opportunity gaps exist along race and class lines, and highlight the potential for increased gender stereotyping.

Tanzania: E-Reader Technology Boosts Girls' Education

go.nmc.org/tanzlearn

(Joanna Martin, *Tanzania Daily News*, 27 May 2017.) The transition from primary to secondary school, where classroom instruction moves from Swahili to English, is one of the most potent fail points for girls in Tanzania. A structured English literacy program that utilizes e-readers is positively impacting girls' language abilities and building confidence, leading to more girls continuing in secondary school.

Who Is Shaping Girls' Education Globally?

go.nmc.org/girlworld

(Christina Kwauk and Amanda Braga, *Brookings*, 7 March 2017.) The girls' education movement is being impacted by general declines in education-related aid globally. Research and regular reporting on trends in educational access for girls are helping to raise awareness of effective interventions; more analysis on quality of learning environments would help inform advancements in gender equality.

Why More STEM Classes Won't Help Solve the Serious STEM Achievement Gap

go.nmc.org/stemhands

(Valerie Strauss, *The Washington Post*, 10 August 2016.) In STEM fields, critical skills include creativity, collaboration, and problem-solving. To help low-SES students succeed in STEM pathways, schools do not need to provide more technology, but rather access to hands-on learning experiences through the arts, sports, and civic engagement.

Sustaining Innovation through Leadership Changes



Wicked Challenge: Those that are complex to even define, much less address

Multiple resources, including funding, time, and personnel, are required to effectively implement the innovative teaching and learning pedagogies highlighted throughout this report. Disruption to any one of these resources leaves organizations scrambling to fill the missing pieces. The process of preparing for the unknown is not always well defined, nor is it currently the norm in K–12 schools. Unfortunately, leadership vacancies or transitions can result in project delays or hinder the development and growth of programs designed to effectively meet student needs. Turnover can also render promising initiatives without a driver, especially if a clear innovation strategy is not implemented to propel sustainable change and if other participants do not feel a sense of ownership over the program. Schools must identify successful strategies for making continued progress on promising innovations in the face of transitioning authority or run the risk of stalling initiatives that could lead to increased student success.²³⁵

Overview

Having made its inaugural appearance in the NMC's 2016 strategic brief *Scaling Solutions to Higher Education's Biggest Challenges*,²³⁶ this topic is stimulating conversations around educational leadership and its impact on school initiatives. Planning for and implementing innovative approaches to improve student success requires dedication from school leadership, faculty, and staff. According to Estyn, an independent research organization that provides educational assessments for the Welsh government, leadership is "the most important influence in raising standards [and] improving teaching and learning."²³⁷ Leadership initiatives can significantly impact the discovery, adoption, and implementation of new pedagogical strategies. One notable aspect contributing to the wickedness of this challenge is the complexity of defining leadership in schools.

Within schools, multiple layers of authority exist — including teachers in each classroom, a single principal for a school, and superintendents of districts.²³⁸ In addition, "middle leaders," who act as liaisons between principals and teachers, have recently emerged within the UK, Australia, and parts of Asia. Proponents believe

the emergence of this position will alleviate some of the burdens for educators, freeing up time for more efficient assessment of teacher performance and strategy sessions that will influence future teaching initiatives; however, they add to the complexity of school hierarchies.²³⁹ Involvement from all levels of leadership is essential for the successful development and deployment of programs that focus on increasing student success while developing learners' 21st-century skills. These initiatives shift the role of teachers from depositors of knowledge to mentors working alongside students; this transition, commonly referred to as "rethinking the roles of teachers," is featured as a difficult challenge earlier in this report. To bolster initial success and future sustainability, instructors must be adequately supported in these changing roles by strong leadership and clear goals.²⁴⁰

Sustainability for long-term success is a vital consideration when developing new pedagogical programs, especially as external factors such as funding and leadership are prone to change. For example, evidence shows that a new principal will take at least five years to develop a vision and implement new policies and initiatives that showcase positive learner impacts.²⁴¹ Stable leadership impacts the sustainability of innovation initiatives. Another facet of this challenge is the relatively high teacher and principal turnover rates faced by schools. Recent research highlights the shortage of teachers within the US, predicted to rise to 112,000 by 2018.²⁴² Further, reports published in England's House of Commons showcase concern for decreasing retention rates of primary and secondary teachers in specific geographic regions of the country.²⁴³ The challenge for schools is not only in developing actionable solutions to prevent turnover, but also in recruiting instructors to fill the gaps.

Implications for Policy, Leadership, or Practice

As previously stated, the context in which school leaders feel empowered to introduce new teaching and learning strategies must be taken into consideration to ensure the long-term sustainability of any project. Therefore, rules and procedures governing these implementations are key to their success. Research published by the HEAD Foundation, a think tank based out of Singapore, surfaces how countries like India and Malaysia are adopting and

adapting policies from high-performing schools in other countries to establish innovative teaching practices within their own curricula. One facet of this strategy is to understand the leadership landscape and how schools can develop and identify innovative instructors to help promote interest in these types of projects.²⁴⁴ Clarity Innovations, an edtech-focused organization, has also published multiple toolkits and sample policies that can help guide schools in developing their own guidelines to ensure effective change in the classroom.²⁴⁵ K–12 schools can also learn from strategic policies established by higher education institutions. For example, the State Educational Technology Directors Association lists leadership as the first essential condition to the successful implementation of digital learning.²⁴⁶

Leaders can identify pioneer programs working to overcome this challenge to emulate on their own campuses. For example, Ashoka Canada's Changemaker Schools recently announced its first cohort of schools to participate in building a network of educational leaders who will share their efforts to transform their schools by leveraging new pedagogical and technological tools to develop future-ready students.²⁴⁷ In England, several nonprofit organizations are collaborating on the School Leadership Challenge: 2022 program, which is working proactively to document, assess, and develop solutions to combat the rising concern of teacher retention and recruitment. While the focus of this initiative is to better understand how to develop effective leadership, schools can look to this program's findings to guide the development of sustainable change that promotes transformational teaching and learning strategies.²⁴⁸

The Fund, a Chicago-based nonprofit, has developed a new program that aims to place principals in schools that best align with their experiences. This initiative, known as The Right Match, sets principals up for success by matching their skills to a school environment that will benefit most from their expertise.²⁴⁹ In North Carolina, James Martin Middle School has published its annual Improvement Plan that documents the resources and innovation initiatives the school will implement throughout the year. Listed in the plan is the development of projects that upskill students to meet the technology-based demands in the workforce. Schools can use the plan as a template to aid their own planning in efforts to identify prospective programs and outline the leadership strategies essential to their adoption and long-term success.²⁵⁰

For Further Reading

The following resources are recommended for those who wish to learn more about the sustaining innovation through leadership changes:

Developing Sustained, Effective Middle Leadership: Keys to Success

go.nmc.org/effc

(Liz Worthen, Optimus Education, 10 August 2016.) A lack of middle leadership in schools leads to an ineffective learning environment. It is important to take time to develop and train existing staff in leadership skills.

Four Ways School Leaders Can Support Meaningful Innovation

go.nmc.org/innv

(Justin Reich, KQED Inc., 8 January 2017.) Administration can play a guiding role in implementing innovation. Facilitating teacher ability in research and development and collectively learning from student experience are great starting points.

How Much Is “Too Much” Change for a School District?

go.nmc.org/allo

(Larry Spring, Allovue, Inc., 4 April 2017.) Many leaders overestimate their capacity to support change. This article demonstrates a way to calculate how each institution member might be affected as a result of a particular change initiative.

The Relationships among Instructional Leadership, School Culture, and Student Achievement in Kentucky Elementary Schools

go.nmc.org/tuck

(Karen H. Mackey, *Dissertations*, 2016.) As principals are being pressured for school improvement, they have shifted to taking instructional leadership roles. This research indicates how student achievement is affected as a result.

Transforming Schools: How Distributed Leadership Can Create More High-Performing Schools

go.nmc.org/trib

(Chris Bierley et al., Bain & Company, 14 January 2016.) This study finds that, rather than training principals to be transformational leaders, training all instructors to engage in distributive leadership strategies will enable quicker innovation in schools.

Why Do Teachers Leave?

go.nmc.org/teac

(Learning Policy Institute, 2016.) Teachers leave institutions for a myriad of reasons including lack of preparation, challenging work conditions, and dissatisfaction with compensation. This report reveals ways to support teachers and slow their exodus.

Important Developments in Educational Technology for K–12 Education

The six developments in educational technology detailed in this section were selected by the project's expert panel using the Horizon Project's Delphi-based process of iterative rounds of study, discussion, and voting. In the NMC Horizon Project, educational technology is defined in a broad sense as tools and resources that are used to improve teaching, learning, and creative inquiry. While many of the technologies considered were not developed for the sole purpose of education, they have clear applications in the field.

The technology developments that the members of the expert panel agreed are very likely to drive technology planning and decision-making over the next five years are sorted into three time-related categories: near-term developments that are expected to achieve widespread adoption in one year or less; mid-term developments that will take two to three years; and far-term developments, which are forecasted to enter the mainstream of education within four to five years. Each technology development opens with an overview of the topic.

The initial list of topics considered by the expert panel was arranged into categories that were based on the primary origin and use of the technology. The potential applications of the featured technologies, specifically in the context of global K–12 education, were considered in a series of online discussions that can be viewed at go.nmc.org/2017-k12-tech.

The expert panel was provided with an extensive set of background materials when the project began that identified and documented a range of existing technologies used in both education and beyond. The panel was also encouraged to consider emerging technologies whose applications for schools may still be distant. They also proposed developments in technology that were new to the NMC Horizon Project; a key criterion for the inclusion of a new topic in this edition was its potential relevance to teaching, learning, and creative inquiry in K–12 education.

In the first round of voting, the expert group reduced the master set, shown on the following page, to 12 developments in technology that were then researched in much greater depth by the NMC staff. Each was then

written up in the format of the *NMC Horizon Report* and used to inform the final round of voting. Technology developments that do not make the interim results or the final report are often thoroughly discussed on the project workspace at go.nmc.org/2017-k12-workspace. Sometimes a candidate technology does not get voted in because the expert panel believes it is already in widespread use in K–12 education, or, in other cases, they believe the technology is more than five years away from widespread adoption. Some technologies, while intriguing, do not have enough credible project examples to substantiate them.

There are currently seven categories of technologies, tools, and strategies for panelist use that the NMC monitors continuously. These are not a closed set but rather are intended to provide a way to illustrate and organize technologies into pathways of development that are or may be relevant to learning and creative inquiry. The list of seven categories has proved fairly consistent, but new technologies are added within these categories in almost every research cycle; others are merged or updated. Collectively, the categories serve as lenses for thinking about innovation; each is defined below.

- > **Consumer technologies** are tools created for recreational and professional purposes and were not designed, at least initially, for educational use — though they may serve well as learning aids and be quite adaptable for use in schools. These technologies find their ways into institutions because people are using them at home or in other settings.
- > **Digital strategies** are not so much technologies as they are ways of using devices and software to enrich teaching and learning, whether inside or outside the classroom. Effective digital strategies can be used in both formal and informal learning; what makes them interesting is that they transcend conventional ideas to create something that feels new, meaningful, and 21st century.
- > **Enabling technologies** are those technologies that have the potential to transform what we expect of our devices and tools. The link to learning in this category is less easy to make, but this group of technologies is where substantive technological innovation begins

to be visible. Enabling technologies expand the reach of our tools, making them more capable and useful.

- > **Internet technologies** include techniques and essential infrastructure that help to make the technologies underlying how we interact with the network more transparent, less obtrusive, and easier to use.
- > **Learning technologies** include both tools and resources developed expressly for the education sector, as well as pathways of development that may include tools adapted from other purposes that are matched with strategies to make them useful for learning. These include technologies that are changing the landscape of learning, whether formal or informal, by making it more accessible and personalized.
- > **Social media technologies** could have been subsumed under the consumer technology category, but they have become so ever-present and so widely used in every part of society that they have been elevated to their own category. As well established as social media is, it continues to evolve at a rapid pace,

with new ideas, tools, and developments coming online constantly.

- > **Visualization technologies** run the gamut from simple infographics to complex forms of visual data analysis. What they have in common is that they tap the brain's inherent ability to rapidly process visual information, identify patterns, and sense order in complex situations. These technologies are a growing cluster of tools and processes for mining large data sets, exploring dynamic processes, and generally making the complex simple.

The following pages provide a discussion of the six technology developments highlighted by the 2017 K–12 Expert Panel, whose members agreed that they have the potential to foster real changes in education, particularly in the development of progressive pedagogies and learning strategies, the organization of teachers' work, and the arrangement and delivery of content. Each topic includes an overview of the technology; a discussion of its relevance to teaching, learning, or creative inquiry; and curated project examples and recommendations for further reading.

Consumer Technologies

- > Drones
- > Real-Time Communication Tools
- > Robotics
- > Wearable Technology

Digital Strategies

- > Games and Gamification
- > Location Intelligence
- > Makerspaces
- > Preservation and Conservation Technologies

Enabling Technologies

- > Affective Computing
- > Analytics Technologies
- > Artificial Intelligence
- > Dynamic Spectrum and TV White Spaces
- > Electrovibration
- > Flexible Displays
- > Mesh Networks
- > Mobile Broadband
- > Natural User Interfaces
- > Near Field Communication
- > Next Generation Batteries
- > Open Hardware
- > Software-Defined Networking
- > Speech-to-Speech Translation
- > Virtual Assistants
- > Wireless Power

Internet Technologies

- > Bibliometrics and Citation Technologies
- > Blockchain
- > Digital Scholarship Technologies
- > Internet of Things
- > Syndication Tools

Learning Technologies

- > Adaptive Learning Technologies
- > Microlearning Technologies
- > Mobile Learning
- > Online Learning
- > Virtual and Remote Laboratories

Social Media Technologies

- > Crowdsourcing
- > Online Identity
- > Social Networks
- > Virtual Worlds

Visualization Technologies

- > 3D Printing
- > GIS/Mapping
- > Information Visualization
- > Mixed Reality
- > Virtual Reality

Makerspaces

Time-to-Adoption Horizon: One Year or Less



Makerspaces are physical environments that foster opportunities for hands-on learning and creation, often enabled by emerging technologies. As schools increasingly focus on methods to foster the development of 21st-century skills in students to prepare them for the demands of the global technological economy,²⁵¹ makerspaces are viewed as an important bridge. A growing number of classrooms, libraries, and community centers are being transformed into makerspaces, and educators are leveraging maker activities to engage learners in creative, higher-order problem-solving through design, construction, and iteration.²⁵² School leaders are incorporating making into the curriculum to encourage students and teachers to bring to life ideas and to explore design thinking approaches. Makerspaces have also become a vehicle for bolstering student exposure to technical disciplines and entrepreneurial thinking as they creatively leverage technology to address some of the world's pressing challenges by producing innovative solutions.²⁵³

Overview

This topic was first featured in the *NMC Horizon Report: 2015 K–12 Edition* and has appeared in every edition since, accelerating from compelling phenomenon to global movement. Makerspaces are categorized as a development in technology because they are enabled by tools such as 3D printers, laser cutters, and animation software; however, the real focus transcends technology, emphasizing the deep learning experiences and outcomes generated through hands-on activities.²⁵⁴ These workshop environments encourage development of higher-order skills like problem-solving and creativity as students engage in self-directed tinkering. The notion that failure is an essential part of learning is oft-cited but is not always seamlessly ingrained in school culture. Makerspaces champion the process of experimentation and iteration; students design and build, making continuous improvements to prototypes as they learn what works — and what does not.²⁵⁵

The past decade has seen 14× growth in makerspaces, with 1,400 user-reported active spaces around the globe as of 2016. Europe is currently leading the charge, home to nearly 40% of the world's makerspaces.²⁵⁶

As a response to a shrinking labor force in China, the government is heavily investing in maker education to transition away from manufacturing toward innovation to stimulate economic development.²⁵⁷ In the US, libraries at rural and low-income schools are increasingly becoming creation hubs for students who do not have internet or exposure to other technologies at home.²⁵⁸ This development aligns with the root of makerspaces, born out of a desire for public community spaces that democratize access to high-quality tools. Unfortunately, *EdSurge* reports that girls and students of color are still underrepresented in the K–12 maker movement. Solution-oriented programs such as Sunnyvale Library's Make-Her program connect both mothers and their daughters to opportunities to explore technology and gain a passion for engineering together.²⁵⁹

Making has gained significant traction in mainstream education in part because the concept is often used as a catch-all for any hands-on experiences that place learners in the role of creators. Building dedicated spaces for such activities can be perceived as secondary to the true spirit of this trend — integrating the maker mindset into the formal curriculum to spur real-world learning.²⁶⁰ While this ideology is becoming more widely embraced, there is a need to strategize future applications that yield evidence of improved learning outcomes and engagement. The National Science Foundation recently awarded \$1.5 million for five early-concept grants with the aim of cultivating new approaches to making in STEM education. One such project is investigating the cognitive and affective basis of learning through constructing, while another is exploring how makerspaces can generate participation from groups that are historically underrepresented in STEM subjects.²⁶¹

Relevance for Teaching, Learning, or Creative Inquiry

Now that makerspaces have been gaining serious momentum in schools worldwide, research efforts are under way to surface benefits and best practices. Researchers in Denmark recently examined how makerspaces at the International School of Billund (ISB) contribute to primary school students' 21st-century skill development through exploration and play. An early conclusion drawn was that merely assigning open space

is not enough; the environment must be configured in a manner that nurtures creativity and collaboration while promoting both self-directed and peer-to-peer learning. ISB has built the Creator Space, which equips teachers with the skills to help their students more authentically tap into their imaginations. In one project, 4,000 students were tasked with designing and building their own musical instruments, which led not only to the development of tangible products, but also to substantial discussions about the science behind music.²⁶²

While makerspaces were initially lauded for their role in stimulating interest in STEM fields,²⁶³ they are now often viewed as conduits for STEAM curriculum. The act of making infuses elements of artistic design into engineering and technology. Schools increasingly favor multi- and interdisciplinary learning, and makerspaces break down silos to connect all subjects.²⁶⁴ Miami-Dade County Public Schools (MDCPS) are leaders in this movement; students are learning to use programs such as 3D CAD for open-ended projects, such as developing their own toys and vases. Science students also embarked on a project to connect *Adventures of Huckleberry Finn* to their engineering class by building meaningful objects from the book. As a result, students felt more invested in the literature. Further, learners at MDCPS struggling with specific disciplines see makerspaces as outlets where their unique skill sets are valued, especially when engaging in team projects.²⁶⁵

Many makerspaces around the world have adopted unstructured approaches to makerspaces, influencing students to produce in organic ways that suit their personal curiosities. In Australia, the Dawson Library at St. Columba Anglican School is home to the continent's first permanent makerspace in the K–12 sector. The space is dynamic and constantly updated; students are exposed to the latest technologies as they emerge, learning to use Oculus Rift, Goldieblox, Alienware computers, and more. Dawson Library also melds the physical and digital realms with virtual spaces that enable students to connect and collaborate with peers from other schools.²⁶⁶ As makerspaces continue to attract interest worldwide, school leaders and educators can look to organizations such as MakerEd for free resources and professional development to plan and execute them in ways that foster meaningful outcomes for students.²⁶⁷

Makerspaces in Practice

The following links provide examples of makerspaces in use that have direct implications for K–12 education settings:

Lab on Wheels

go.nmc.org/wheels

Through the Infocomm Development Authority of Singapore's Lab on Wheels initiative, more than 25,000 primary school students are writing code and experimenting with robots, wearables, and drones aboard a traveling laboratory with a bus.

Maker School

go.nmc.org/strawb

A Swedish teacher believes any classroom can be transformed into a makerspace; she documents her class's maker activities as her students use tools such as Strawbees to bring their ideas to physical form.

Yorktown High School (YHS) Makerspace

go.nmc.org/yhs

At YHS, the makerspace is seen as an outlet for reducing student stress. Since it was humbly started with donated LEGO bricks, students have amassed high-tech supplies by entering a contest through Khan Academy, Google, and DonorsChoose. One student is 3D printing a prosthetic hand and controlling its movements via an Arduino board.

For Further Reading

The following articles and resources are recommended for those who wish to learn more about makerspaces:

7 Tips for Planning a Makerspace

go.nmc.org/7tips

(Leila Meyer, *THE Journal*, 23 February 2017.) The author cites successful makerspace exemplars across US schools and districts to help when providing recommendations. Tips include swapping out stationary furniture for pieces that are flexible and movable and visiting other makerspaces for inspiration.

60+ Makerspace Ideas for Maker Education

go.nmc.org/60plus

(Makerspaces.com, accessed 2 June 2017.) Want to make an inchworm using LittleBits or teach math concepts through LEGO bricks? Makerspaces.com lists examples of lessons and activities that can be easily implemented in school makerspaces and classrooms.

"Makerspaces" for Science Instruction Also Proving Helpful for English Learners

go.nmc.org/scieng

(Pat Maio, *EdSource*, 16 November 2016.) Students who are learning to speak English are finding makerspaces particularly helpful. Maker activities that involve keeping a journal and deep group discussions are seen as confidence builders.

Robotics

Time-to-Adoption Horizon: One Year or Less



Robotics refers to the design and application of robots — automated machines that accomplish a range of activities. The International Federation of Robotics predicts that 2.5 million industrial robots will be in use by 2019.²⁶⁸ As robots transform industries including military services²⁶⁹ and manufacturing, performing tasks that are unsafe or tedious for humans, many people have concerns about automation's potential for future disruption of other job categories.²⁷⁰ To prepare students for career pathways amid these uncertainties, K–12 educators are harnessing the study of robotics to promote critical and computational thinking as well as to foster hands-on learning in STEM subjects and beyond.²⁷¹ Robotics competitions are providing learners with opportunities to explore STEM challenges²⁷² and to apply their skills toward developing solutions to major global issues.²⁷³ Teachers are also using robots to augment classroom instruction and promote student engagement.²⁷⁴

Overview

As applications of robotics proliferate across multiple sectors, the industry is experiencing tremendous growth. *Research and Markets* predicts that the global robotics industry will increase from \$34.1 billion in 2016 to \$226.2 billion by 2021, with growth in industrial robotics, consumer robots, unmanned aerial vehicles, and autonomous vehicles.²⁷⁵ Amid worries that increased sophistication of robotics will lead to the automation of many jobs, analysts indicate that the careers least likely to be replaced are those involved with responding to unpredictable environments and designing and managing complex interrelated systems.²⁷⁶ While advancements in machine learning and artificial intelligence, discussed later in this report, may eventually minimize humans' roles in coding,²⁷⁷ job market analytics firm Burning Glass reviewed data on US job openings and found that half of the positions requiring coding skills were in industries outside the technology sector, including finance, manufacturing, and health care.²⁷⁸

To ready students for these workforce developments, schools are introducing learners to robotics technologies from a young age. The notion of coding as a literacy detailed earlier in this report will also help

robotics gain additional traction in K–12 education. Further, the study of robotics has value in developing 21st-century skills that students can apply to many fields. A robotics teacher at Roberts McCubbin Primary School in Melbourne has described learner benefits including increased resilience, collaboration, and ability to assess risks.²⁷⁹ Robotics tournaments are cropping up worldwide; teams of students build and program robots to accomplish a defined goal or complete a task the quickest. In recognition of the teamwork and collaboration involved in these events, US states including Minnesota, Connecticut, and Texas have named robotics as an official sport in high schools.²⁸⁰

In addition to integrating robotics instruction into the curriculum, robots have the potential to impact classrooms in a service capacity, facilitating learning activities or serving as teachers' aides.²⁸¹ For example, the TeachAssist service robot can project interactive content²⁸² and use facial recognition technology to track students' performances over time; the robot will be deployed in 15 Dubai schools by the end of 2017.²⁸³ As the use of robots in educational settings increases, a UK researcher has identified two areas of concern for student impact: privacy and relationship-building risks. Any data or information collected about students is subject to breach. Further, young children can perceive a social robot as a trusted friend and confidante, but current models may lack sufficient emotional intelligence to provide needed support.²⁸⁴ However, the benefits may outweigh these risks; robots can provide lessons to children in hospital isolation chambers,²⁸⁵ and students who are chronically ill or homebound can maintain academic progress and social connections through the use of telepresence robots.²⁸⁶

Relevance for Teaching, Learning, or Creative Inquiry

Colleges and universities are partnering with schools to expose students to robotics. For example, University of Georgia faculty are working with 40 local teachers to provide workshops that incorporate problem-based learning into science and math curricula using RoboRobo kits; one project involves building a robotic model of a Venus flytrap. The program aims to increase workforce readiness for regional jobs in health care or engineering.²⁸⁷ Graduate students from the University

of Texas at San Antonio facilitate the Robotics Club at Crockett Elementary School, where students design robots using LEGO bricks and circuitry to complete a series of engineering challenges. The university and the school district are using the collaboration to give students individualized attention and encouragement while co-developing future instructional models.²⁸⁸

Learning about robotics in a K–12 setting can foster the next generation of innovation and provide a venue for students to tackle global and local challenges. For example, fifth- and sixth-grade students from the Gems Modern Academy in Dubai have invented a robot that tracks the sun's movement and adjusts solar panels throughout the day, allowing the panels to capture the maximum amount of sunlight (and energy).²⁸⁹ Further, student teams participating in the 2017 *FIRST* Global Robotics Games, an international competition with entrants from 160 countries, are addressing the water crisis by developing solutions to store drinkable water, filter contaminated water, and find new sources of clean water.²⁹⁰ Another contest, the Pan-African Robotics Competition in Dakar, Senegal, asked students to develop robots for warehouse automation and mining of natural resources. The event aimed to draw attention to the impact of robotics on local economies and encourage government and private investment in STEM education.²⁹¹

Teachers are finding applications for robots in the classroom beyond science and technology curricula. In an American Literature class at Benton High School in Arkansas, students used Spheros, balls that can be programmed using instructional coding apps, to represent the journey of characters in *Adventures of Huckleberry Finn*. Learners engaged in deep reading of the text to identify characters' motivations and collaboratively planned how to represent their findings with the Spheros. As they experience the iterative, experimental nature of the programming process, students are able to better grasp the value of writing techniques, including revision and reflection. For a unit on *The Grapes of Wrath*, an Advanced Placement English teacher in New York built a mountain from cardboard and Astroturf and assigned students to navigate Spheros over the mountain. Students faced challenges as they maneuvered around "traps" on the mountain, and the exercise helped them build empathy for the difficulties faced by the characters in the novel.²⁹²

Robotics in Practice

The following links provide examples of robotics in use that have direct implications for K–12 education settings:

Primary School Kids Invent Cave-Cleaning Robot

go.nmc.org/cavebot

After visiting the Sterkfontein caves and seeing litter dropped by other patrons, sixth-grade students at a South African school designed a robot to clean the caves. The robot's tires can navigate groundwater and sand, so it can pick up trash in areas inaccessible to humans.

Ministry of Local Government Supports Battle for Knowledge Program

go.nmc.org/botprog

The B92 Foundation with the support of the Ministry will provide funds for 213 primary schools in Serbia to purchase robots and implement training for teachers through the Battle for Knowledge initiative, which aims to expose students in grades five through eight to programming and coding and to build a competitive national robotics league.

Year of Robotics 2017: School Girls Inspired to Build Mobile Apps

go.nmc.org/girlstem

As part of Herriot-Watt University's Year of Robotics, female students and faculty hosted a Girls in Computer Science Day where 50 girls from secondary schools across Scotland participated in robotics workshops to bolster interest in STEM careers and increase female representation in STEM industries in the UK.

For Further Reading

The following articles and resources are recommended for those who wish to learn more about robotics:

Can Robotics Teach Problem Solving to Students?

go.nmc.org/roboprob

(Beth Brubaker, *eSchool News*, 20 January 2017.) This article offers practical tips for educators integrating robotics instruction. Recommendations include helping learners understand the trial-and-error process of programming; discussing rubrics for student assessment up-front, including soft skills like collaboration; and building reflection into the activities.

Educational Robotics Matrix

go.nmc.org/robolist

(Drew Price, The Robotics Alliance Project, accessed 6 June 2017.) This website provides a list of regularly updated resources for robotics curriculum, competitions, and internships for K–12 students. The opportunities are divided into sections based on grade level.

Five Reasons to Teach Robotics in Schools

go.nmc.org/robofive

(Matthew Lynch, *The Edvocate*, 8 April 2017.) With the growth of STEM field careers set to increase 17% in the next decade, incorporating robotics into school curricula will better prepare students for the future while also promoting creativity, persistence, and inclusivity.

Analytics Technologies

Time-to-Adoption Horizon: Two to Three Years



The growing focus on measuring learning is a trend found earlier in this report and is accelerating technology adoption in K–12 settings, with analytic technologies as the cornerstone of this trend. Analytic technologies are a diverse array of tools and applications that turn data into actionable information.²⁹³ Data are the currency of the digital economy driving the Information Age.²⁹⁴ In the Information Age, finding ways to collect, connect, combine, and interpret meaning about learner capabilities and progress has the potential to fuel personalized and adaptive learning experiences. In the past 20 years, measuring student learning has evolved from passive and latent metrics like semester/quarter grades, grade-level promotion, and graduation rates to interactive and real-time metrics that recommend adjustments to meet learners' needs and inform teachers' decisions about curriculum and pedagogy. Understanding how to use new data tools and developing analytic skills are essential to advance the use of big data in educational settings.

Overview

Today, almost any interaction made over the internet or through the consumption of goods and services is being tracked, stored, and used in targeted ways. This has led to the notion of big data — massive amounts of data that reflect the behavior and actions of various populations. Gartner, a global and across-industry research and advisory company, estimates that the analytics and business intelligence market will reach \$18.3 billion this year, with substantial growth forecast for the near-term future.²⁹⁵ Data scientists and collection platforms are now able to computationally organize petabytes and exabytes of data so that it is easy to analyze and identify previously undetected patterns. The same technologies that enable consumer outlets such as early adopters Amazon and Netflix to personalize the shopping experience can be used to track student activities, behaviors, performance, and interests to tell a story about individual learners' experiences. When it comes to understanding and facilitating student learning, analytics technologies applied in educational settings are helping institutions move from data-rich and information-poor scenarios to data-driven, AI- and machine learning-supported, research-based, and information-rich scenarios.

The technologies that enable analytics are mostly industry agnostic. While the types of data, scale,

purpose, and other aspects will differ, an analytics infrastructure for K–12 institutions will look similar to retail and commerce applications, and basically the same as higher education applications.²⁹⁶ Examples of analytic technologies include database management systems, data warehouses (structured data) or data lakes (unstructured data), business intelligence reporting tools, visualization software, modeling and predictive analytics tools, and text analysis functions.²⁹⁷ These technologies are not typically tools or applications that individual instructors deploy in their classrooms; rather, they are embedded into the enterprise information technology architecture administered at the school or district level. Next-generation student information systems and learning management systems²⁹⁸ will include real-time learner analytics dashboards with instructor and student views, as well as administrative and parent view options. These views provide insight about learner needs and drive what Gartner calls descriptive²⁹⁹ (what happened) and diagnostic³⁰⁰ (why did it happen) analytics.

Data mining that targets at-risk students with intervention strategies, personalized and adaptive learning programs, and systems with flexible pathways to success are examples of more sophisticated applications of analytic technologies — predictive³⁰¹ (what will happen) and prescriptive³⁰² (how will we make it happen) analytics. As schools become more adept at working with and interpreting big data, they can make more informed decisions that reflect real learner needs. Data can be used to predict learner outcomes, trigger interventions or curricular adaptations, and even prescribe new pathways or strategies to improve student success. Harnessing the power of analytic technologies is key to achieving a better model for optimized learning.³⁰³

Relevance for Teaching, Learning, or Creative Inquiry

Analytic technologies bring together historic, demographic, behavioral, programmatic, performance, social, and other quantifiable aspects of students. There is even software that captures students' facial expressions and generates student engagement feedback to help teachers understand where students are struggling or where they need more challenge.³⁰⁴ When diverse and disconnected data are integrated into an analytics dashboard or alert system, the outcome is rich and immediate feedback; personalized learning

programs, automated guidance, and suggestions for help or alternative pathways are possible. Used in this way, analytics technologies are changing expectations for how students navigate through curriculum and successfully matriculate.

The International Society for Technology in Education describes the evolution of edtech over the past 10 years — from learning to use technology to using technology to transform learning.³⁰⁵ The profuse development of technology with teaching and learning applications can be overwhelming for educators, many of whom were neither taught nor learned to teach with technology-assisted support. Organizations like the Learning Analytics Collaborative help make sense of the practical applications of analytics in education by bringing together a global community of educational visionaries, researchers, and data scientists to address issues like analytics-powered deeper learning approaches, to address concerns about data privacy, and to inform practices to humanize machine learning and AI support.³⁰⁶ Analytics technologies have the potential to transform learning by converting data about learners into understandable, meaningful, and actionable information. Khan Academy is a mainstream example for how analytics technologies can be packaged to create an adaptive and informed learning experience. The site continually assesses learner progress by incorporating algorithms to adapt the curricular content to teach for mastery before advancing students to the next level of learning.³⁰⁷ This adaptive technology is coupled with teacher, learner, and parent views of progress.

In addition to classroom applications of analytics, these same technologies can help students explore college and future career path options. Consider the relationship analytics that drive online dating services and how these same algorithms can be applied to high school students exploring matches to their interests, skills, and experiences with possible majors and prospective colleges/universities. LinkedIn is beginning to explore using big data and analytics to provide customized college and career pathway recommendations.³⁰⁸ Analytics technologies deployed in educational settings are nascent when compared to retail, consumer, and even relationship analytics. Other industries have examples of successes and failures for educational leaders to consider as they make decisions about analytics priorities and investments. As analytics technologies evolve and the talent and tools in educational settings mature, schools are adjusting how they support teachers and teachers are adjusting how they support learners.

Analytics Technologies in Practice

The following links provide examples of analytics technologies in use that have direct implications for K–12 education settings:

AltSchool's Big Data Model

go.nmc.org/altsc

AltSchool quantifies student activities, performance, and behaviors and transforms those data into information and actions that personalize individual learning experiences. This exemplary lab school is a partnership between entrepreneurs, educators, and engineers driven to make education personal.

Analytics Driving Intervention Activities

go.nmc.org/tapbig

Hattiesburg (Mississippi) Public School District and Spokane (Washington) Public Schools are using analytics technologies to spot “at-risk” trends and trigger early intervention tactics to better address student needs.

INTUITEL

go.nmc.org/intu

The INTUITEL system, funded by education partners from the EU, monitors each learner’s progress and behavior, combines these data with pedagogical and methodological knowledge, and then deduces optimal guidance and feedback.

For Further Reading

The following articles and resources are recommended for those who wish to learn more about analytics technologies:

2017: The Year That Data and Analytics Go Mainstream

go.nmc.org/theeye

(Rob van der Meulen, Gartner, 24 January 2017.) This *Smarter With Gartner* publication explains the ways in which organizations use data and analytics to drive data-informed decisions. Many analytics technologies are industry agnostic and education can learn from the advanced applications of analytics in other industries.

Analytics-Enabled Adaptive Learning

go.nmc.org/peade

(EdSurge, *Decoding Adaptive*, 2016.) This special report by Pearson and EdSurge provides a common definition and framework for understanding adaptive learning in practice. The report also unpacks the underlying analytics technologies and data needed to run successful adaptive learning initiatives.

Learning Analytics

go.nmc.org/learn

(Office of Educational Technology, US Department of Education, accessed 10 July 2017.) This brief and companion publication summarizes data mining and data analytics as they apply to learning. It outlines the research possibilities and practical applications of analytics in educational environments as related to the US Department of Education’s National Educational Technology Plan. Specifically, it addresses ways to use online learning system data to improve instruction.

Virtual Reality

Time-to-Adoption Horizon: Two to Three Years



Virtual reality (VR) refers to computer-generated environments that simulate the physical presence of people and/or objects and realistic sensory experiences. At a basic level, this technology takes the form of 3D images that users interact with and manipulate via a computer interface.³⁰⁹ VR devices break down into two categories: high-end headsets, such as the Oculus Rift, HTC Vive, or Sony PlayStation VR, and budget headsets that include the Samsung Gear VR and Google Cardboard along with accessories like headphones and haptic controller accessories.³¹⁰ Contemporary applications allow users to more authentically “feel” the objects in these displays through gesture-based and haptic devices, which provide tactile information through force feedback. VR models can be created using a variety of CAD software such as Tinkercad, Unity, and Sketchfab. These content creation tools along with the viewers can make learning more authentic, allow for empathetic experiences, and increase student engagement.^{311, 312}

Overview

As pedagogies that favor student-centered learning approaches continue to take hold across the world, tools such as VR that enable more experiential learning opportunities are increasingly valued. The same technology used to simulate virtual experiences in medical and military training for years is now of interest to schools because it can provide students with simulated firsthand experiences.³¹³ Through VR, schools can transport learners to distant and impossible-to-visit locations. In the sciences, abstract concepts such as observing the impact of a hurricane or getting an up-close view of how blood moves through veins are now possible. With regard to geography and culture, students can seamlessly move from one virtual city to another, taking in sights and sounds of a historical site or natural wonder.³¹⁴ Placed on the mid-term horizon, the growing availability of content and the reduction in hardware costs make this a compelling technology to watch.

The year 2016 was big for virtual reality as nearly 100 million VR units shipped — a clear majority of this tally from the proliferation of low-cost Google Cardboard.³¹⁵ In October 2016, the *New York Times* disrupted traditional journalism when they sent Google Cardboard viewers

to 1.3 million people, providing access to a VR film on the global refugee crisis and a new method for telling compelling stories. Even NASA and *National Geographic* have experimented with this visualization technology by creating free classroom-ready content.³¹⁶ Penetration is set to dramatically increase in 2017 as the International Data Corporation forecasts that global revenues for augmented reality and virtual reality will total \$13.9 billion this year, up from \$6.1 billion in 2016. In the education realm, Goldman Sachs predicts that VR could reach 15 million learners by 2025.³¹⁷

Despite widespread interest and the growing availability of educational content, it will take a few years before VR becomes vital to schools around the world. A survey of educational institutions by Extreme Networks found that although over half of respondents are investigating VR, only a quarter are currently using it in the classroom, while only 3% are teaching students to create VR content.³¹⁸ The transformation of textbooks is seen by some to be the main driver in the evolution of VR in schools. Publishers Pearson and Houghton Mifflin Harcourt, for example, are partnering with Google to expand the tech giant’s Expeditions VR field trips, and Pearson is also working with Microsoft on applications of mixed reality for use on the HoloLens. Additionally, Discovery Education is integrating VR into its digital curriculum portfolio; more suppliers will likely take part in the coming years.³¹⁹

Relevance for Teaching, Learning, or Creative Inquiry

Ministries of education (MOEs) worldwide have taken note of the potential of virtual reality in the classroom and have been eager to pilot this technology in the curriculum. In Singapore, the MOE is working with a local start-up and production company to create virtual field trips; the goal is not to replace in-person voyages, but to augment curriculum by supplanting textbook exploration with virtual visits. Teachers have already noted that students’ answers to post-visit worksheets are more insightful than before the introduction of the tool.³²⁰ Similarly in the United Arab Emirates, a pilot project by the MOE is using VR to help science-specializing public school students view the destructive effects of climate change and tour the International Space Station.³²¹

Virtual field trips are not the only way students can benefit from VR in the classroom. At Lincoln Elementary in California, a fifth-grade science class is using the computer application Lifelike to view 3D images of plants, animals, and geographic features. Students can select from 1,000 images and get up-close annotated views of specimens such as beetles and dinosaurs that they can drag into a digital science report.³²² Washington Leadership Academy is also using VR to further its science curriculum. As a winner of a \$10 million grant, it is creating the nation's first virtual chemistry lab, where children can create virtual experiments using chemicals such as sulfuric acid, mercury, or lead without risk of harm and at a fraction of the cost of a brick-and-mortar lab.³²³ In China, where VR in education is developing rapidly due to the proliferation of low-cost platforms and government interest, industry is testing the combination of adaptive learning tools with VR to create personalized instruction that can read cues of boredom and adjust a lesson to increase attention.³²⁴

While studies of immersive VR in the classroom are scarce, several investigations are showing promising results. A recent GfK survey of US K–12 educators commissioned by Samsung found that 85% of teachers agree that VR would help their students understand learning concepts and facilitate greater collaboration, and 84% believe the technology would increase student motivation. Chinese researchers investigated VR's impact on academic performance in language learning and found a 32% increase in retention rates in test groups.³²⁵ Foundry10, a team of researchers, teachers, and educators exploring several research questions around VR, may help provide a better understanding of its use in education in the US and Canada. Their 2017–18 study will focus on the technology's value in the learning environment, the role of empathy in VR, and more.³²⁶

Virtual Reality in Practice

The following links provide examples of virtual reality in use that have direct implications for K–12 education settings:

Experiencing the Solar System with Mixed Reality

go.nmc.org/solr

Seventh graders get a lesson in natural sciences with HoloLens, Microsoft's mixed reality goggles. The use and potential of virtual reality, mixed reality, and augmented reality in the K–12 classroom is discussed.

Japan's First School Dedicated to Virtual Reality Opens

go.nmc.org/japn

Japan's first virtual reality academy opened in April to address the latest demand for knowledge of such

technologies. Tuition is a non-issue as the school is funded by companies eager for fresh talent.

Students Try Out Virtual Reality Program, with Empathy in Mind

go.nmc.org/emth

A middle school teacher implements a virtual reality device intended to instill empathy in her students. She has students take turns following a whale, visiting the moon on *Apollo 11*, and even hopes to have them follow a Syrian refugee girl in her camp.

For Further Reading

The following articles and resources are recommended for those who wish to learn more about virtual reality:

Google Is Bringing VR to One Million UK School Children

go.nmc.org/ukvr

(Amelia Heathman, *Wired*, 15 November 2016). Google launches Google Expeditions in the UK to one million children. Lectures will be linked to supporting VR content, creating an immersive experience daily.

The Rise of Virtual Reality in Education

go.nmc.org/rise

(Mark Grayson, TDMB, 19 December 2016). As adoption grows, virtual reality is being most commonly used in education. It can be used for lectures, learning platforms, and even to visit other schools while sitting in class.

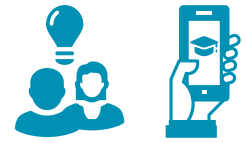
Why VR Matters, Especially in Rural Schools

go.nmc.org/rurl

(Jennifer Carolan, Oath Inc., 19 September 2016). Research shows the increasing isolation of children in rural communities. Experiences can bridge the gap between poor and affluent children, and VR can serve as the great equalizer by offering experiences outside small towns and cities.

Artificial Intelligence

Time-to-Adoption Horizon: Four to Five Years



In the field of artificial intelligence (AI), computer science is being leveraged to create intelligent machines that more closely resemble humans in their functions. Among other facets, AI encompasses machine learning, in which computers' capacities for making decisions and predictions are informed through exposure to massive data sets,³²⁷ and natural language processing, which aims to help humans interact with machines similarly to how they interact with each other.³²⁸ These capabilities are driving a host of developments in industries including health care, financial services, and education.³²⁹ AI applications have the potential to positively impact teaching and learning by enhancing students' metacognition, providing insights into effective pedagogies, and relieving instructors of tedious tasks. As underlying technologies continue to develop and become ubiquitous, it will be important for educators to expose students to AI to prepare them for workforce changes and to apply critical thinking to ethical questions arising from AI use.³³⁰

Overview

International Data Corporation, a market analysis firm, has forecast that global revenues from AI solutions will jump from \$8 billion in 2016 to over \$47 billion by 2020.³³¹ AI is poised to impact many aspects of modern life; for example, IBM's Watson for Drug Discovery used machine learning to expedite identification of genes related to ALS, also known as Lou Gehrig's disease.³³² Further, driverless cars powered by AI technology could lead to decreased deaths on roadways and alter decisions about where people live in relation to their workplaces.³³³ Because of AI's potential for profound disruption to societies, the European Economic and Social Committee (EESC) recently recommended that the EU should create ethical guidelines and labor strategies to be adopted across its member states. The EESC also called for the development of a European open-source infrastructure to promote accessibility and sustainability in future AI technologies.³³⁴

AI systems accomplish tasks and make decisions based on inferences drawn from machine learning or from consumption and processing of massive data sets.³³⁵ Researchers at Princeton University and the University of Bath have shown that AI can learn and adopt racial and gender prejudices from data sets composed of human-generated text.³³⁶ They also found that Google Translate

exhibited gender biases — when translating Turkish sentences with gender-neutral pronouns into English, the software dispensed “He is a doctor” and “She is a nurse.”³³⁷ These findings indicate a need for continued attention to ethics in AI development; further, educators can use these findings to spur conversations in the classroom around psychology and design thinking in technology.³³⁸ Universities are leading the charge on investigating the application of AI to positively influence society; UC Berkeley's Center for Human-Compatible Artificial Intelligence seeks to design AI to reflect human values, while USC's Center on Artificial Intelligence for Social Solutions brings together scientists and social workers to apply AI in addressing pervasive social problems.³³⁹

Many children are encountering AI in the home in the form of virtual assistants such as Amazon's Alexa, Microsoft's Cortana, and Google Home. While the implications for children's social development and language skills as they interact with artificially intelligent objects are not yet known,³⁴⁰ the landscape continues to evolve as the technologies advance. For example, scientists at Tsinghua University in Beijing and the University of Illinois have developed the Emotional Chatting Machine, a chatbot that provides empathetic responses to user input according to the user's selected mood. This development holds potential for future AI to assist in teaching children with autism spectrum disorders about social interactions. These capabilities may also impact the next generation of AI-enabled digital assistants and interactive products.³⁴¹

Relevance for Teaching, Learning, or Creative Inquiry

In the consumer sector, Facebook has articulated that today's AI technologies cannot adequately remove hate speech from the platform, citing the complexities of contextual assessment that still require human work.³⁴² In the same vein, current iterations of AI in education are not yet equipped to supplant teachers' roles in building complex skills including critical thinking, empathy, and creativity³⁴³ — crucial outcomes further discussed in the Deeper Learning Approaches section of this report. AI can extend teachers' abilities to foster collaborative learning environments; a report from education company Pearson and University College London describes the possibilities of virtual agents facilitating and moderating students' small-group discussions.³⁴⁴ Machine learning

can also assess learner progress, providing students with insights that promote self-awareness and self-directed inquiry.³⁴⁵ Additionally, educators can utilize AI software for rote, administrative tasks such as grading, allowing more time to focus on curriculum development and student needs.³⁴⁶

Data from AI technologies can illuminate patterns to help educators improve their pedagogies. For example, students at Pakeman Primary School in London are paired with math tutors based in India and Sri Lanka through Third Space Learning, an online platform. AI capabilities in the platform's software monitor the lessons and provide instructors with real-time alerts if they speak too quickly or fail to allow time for questions. The company is collaborating with University College London scientists to identify successful teaching strategies using AI.³⁴⁷ Additionally, machine learning can enable the personalization of instruction,³⁴⁸ while teachers can gain insight into individual learners' journeys to find where they struggle. The Gwinnett County Public Schools in Georgia are piloting the Vocabulary Learning App, a program in which learners build language skills through activities featuring *Sesame Street* characters. The app uses IBM Watson's AI technologies including natural language processing and pattern recognition to customize the pace of lessons for each student. Teachers can monitor learners' progress through an instructor dashboard.³⁴⁹

A professor at Carnegie Mellon University has noted that some school districts lack resources to update computer science curricula to prepare students for an AI-enabled workforce, while other educators have not been adequately trained to integrate AI into the classroom.³⁵⁰ One solution is incorporating AI elements into pre-service teacher training. First Class is a virtual classroom environment developed at Pennsylvania State University. Pre-service teachers can interact with AI-enabled "students" to test out teaching strategies and build skill sets to keep learners engaged. The AI capabilities allow future teachers to monitor virtual students' attention levels and responses to actions such as addressing learners by name. These simulations will better prepare pre-service teachers for the classroom and provide initial exposure to AI in an educational setting.³⁵¹

Artificial Intelligence in Practice

The following links provide examples of artificial intelligence in use that have direct implications for K–12 education settings:

3 Ways G Suite Updates Use Machine Intelligence to Make Classrooms More Efficient

go.nmc.org/gsuit

Google has streamlined G Suite features to save teachers time and to ease learning for students. For example, the Explore feature in Google Sheets uses natural language

processing to create formulas using students' plain-text questions.

IBM Watson's Chief Architect Talks Democratizing AI, Starting with Fifth Graders

go.nmc.org/ibmai

An IBM executive works with a team of fifth-grade girls in Westchester, New York, on AI challenges for competitions. The group recently designed a device that uses IBM Watson technology to deter birds from flying into glass buildings by identifying the birds' species and emitting predator calls.

Robot in the Classroom: AI to Sit This Year's Gaokao Exam

go.nmc.org/gaokao

AI-MATHS, an artificial intelligence system developed in Chengdu, China, will take the National College Entrance Exam, or Gaokao. By assessing its performance in applying the boundaries of the written questions to the math problems, researchers hope to better understand how to continue development of the system's natural language processing.

For Further Reading

The following articles and resources are recommended for those who wish to learn more about artificial intelligence:

Artificial Intelligence Enters the Classroom

go.nmc.org/lowai

(Nigel Roberts, *NewsOne*, February 2017.) While AI-enabled platforms are providing data on student performance, not all learners have access to these technologies in the classroom. Educators who serve low-income students and students of color often do not utilize AI and other technologies due to districts' lack of funding or because their students cannot access high-speed internet at home.

Artificial Intelligence in Schools Is Closer Than You Think

go.nmc.org/schai

(Christine Nasserghodsi, *Forbes*, 17 February 2017.) The full integration of AI in schools could mean a reimagined approach to a typical school day. The technology will power adaptive learning programs, constantly updated content, high-touch personalization, and more.

Top Nine Ethical Issues in Artificial Intelligence

go.nmc.org/aieth

(Julia Bossman, World Economic Forum, 21 October 2016.) Emerging AI technologies are bringing ethical issues to light. This article examines questions around unemployment, wealth inequality, and prejudices in machine learning.

The Internet of Things

Time-to-Adoption Horizon: Four to Five Years



The Internet of Things (IoT) consists of objects endowed with computing power through processors or embedded sensors that are capable of transmitting information across networks. These connections allow remote management, status monitoring, tracking, and alerts.³⁵² Virtually all sectors have been impacted by the IoT: consumer applications such as smart appliances are proliferating,³⁵³ while industries including health care, retail, agriculture, and manufacturing are benefitting from increased efficiencies of IoT technologies.³⁵⁴ Municipal governments are applying the capabilities of the IoT, leveraging real-time data to centralize information and improve access to services for their citizens.³⁵⁵ Schools are also using smart technologies to lower energy costs and elevate safety measures. As educational applications of IoT technologies advance, schools will have enhanced abilities to track learner information and better understand how certain actions can impact student achievement. However, these affordances must be balanced by implications for privacy and security.³⁵⁶

Overview

An increasing number of everyday objects have become internet enabled, including fitness trackers and smart home items like refrigerators, light bulbs, and thermostats.³⁵⁷ US-based technology company Cisco predicts that by 2021, there will be 27.1 billion internet-connected devices — three times the human global population.³⁵⁸ The research firm Gartner, Inc., has forecast that in 2017, connected things in use worldwide will number 8.4 billion. On the consumer side, the most-used devices will be smart TVs and digital cable boxes, while businesses will utilize smart electric meters and security cameras.³⁵⁹ As the IoT matures, companies and governments are harnessing the power of smart technologies to impact how people make purchases, use transportation, and access information. The Chinese internet services firm Baidu is investing in development of an artificial intelligence platform to create a smart digital assistant in the vein of Amazon's Echo.³⁶⁰

Through the smart-cities movement, municipalities worldwide are addressing challenges related to population growth and improving responsiveness to environmental events through IoT technologies that feed information to centralized management systems. In Rio de Janeiro, an operations center uses sensor data

to monitor and anticipate landslides and flooding, while the city of Santander, Spain, measures traffic patterns through sensors that update the SmartSantanderRA mobile app in real time for its citizens.³⁶¹ These initiatives are enabled by infrastructure investments that power connectivity and promote sustainable growth. Schools are also beginning to explore the IoT's capabilities. Cheshire Public Schools in Connecticut has installed smart lighting that responds to daylight conditions and automatically shuts down during the evening; thus, the district decreased its electricity bill by 84%.³⁶²

While IoT projects that produce financial savings will continue to gain attention, networking solutions provider Extreme Networks surveyed education IT managers and found that obstacles to IoT adoption include costs, security, and privacy concerns.³⁶³ Conversely, the IoT's explosive growth in the consumer sector may be fueled by a willingness to accept less-than-robust security for devices and data.³⁶⁴ The Horizon expert panel has identified the IoT as four to five years from mainstream use in education; nevertheless, school leaders should begin planning today to ensure data security and protect against cyberattacks. Stanford University, Vanderbilt University, and University of California, Berkeley, have experienced incidents in which flyers containing incendiary hate speech were printed out across their campuses by unknown users who accessed unsecured machines via the internet.³⁶⁵ Further, the FBI recently issued a notice cautioning consumers about the potential for privacy breaches through internet-connected toys that record voices and GPS locations.³⁶⁶

Relevance for Teaching, Learning, or Creative Inquiry

George Siemens, a leader in the field of analytics and learning technologies, has predicted that schools will harness the IoT to translate physical information into digital space. Moving beyond simple attendance tracking, smart ID cards could determine how learners move through the school during the day and with whom they interact — and these actions' impacts on student learning and achievement. Siemens cautions that security and privacy considerations must be paramount as schools contemplate IoT applications.³⁶⁷ As these technologies permeate learners' lives in school and at home, hands-on opportunities can help build the next generation of innovators. In partnership with Mozilla, St.

Anne's-Belfield School in Charlottesville, Virginia, recently hosted the SPARK! Hackathon, an event to engage young people in creative thinking around IoT technologies. Students from 12 local high schools worked in teams with industry mentors to design IoT devices; one group created a smart mirror to display daily information and alerts to prepare for the day's activities.³⁶⁸

As seen with municipal projects, schools' investments in technology infrastructure can pave the way for improved access to information and services through smart technologies. India's Central Board of Secondary Education recently directed schools to adopt cashless transaction technologies for examination fees and other expenses.³⁶⁹ Following this change, adoption of IoT-enabled ID cards could also allow learners to buy meals or supplies at school; purchases could be monitored by parents through online accounts.³⁷⁰ In Texas, the Huntsville Independent School District is piloting a fleet of 15 smart buses outfitted with Wi-Fi technology to extend access to learning opportunities. Students can use the Wi-Fi to complete homework during their transit, an app with GPS tracking provides families with information about children's arrival times, and mechanical issues can be diagnosed remotely in real time.³⁷¹

The capabilities of the IoT can provide new strategies for schools to improve students' health and safety. Building on recent findings that use of standing desks in the classroom can lower children's body mass index,³⁷² researchers at Texas A&M University are exploring the impact of smart desks equipped with software that prompts users to move periodically. While the current study is focused on office workers in Australia, health or productivity gains could have implications for K–12 education.³⁷³ Further, dangerous incidents involving firearms in K–12 and university settings have become more pervasive across the US in recent years. Some schools are adopting IoT technology to improve safety and emergency responses. For example, Sandcreek Middle School in Idaho has installed software and acoustic sensors that can detect gunshots, locate the building floor in which an incident is unfolding, and automatically send a building floor plan to first responders.³⁷⁴

The Internet of Things in Practice

The following links provide examples of the Internet of Things in use that have direct implications for K–12 education settings:

The Internet of Things Is Coming to Your School

go.nmc.org/iots

Students at John R. Briggs Elementary School in Ashburnham, Massachusetts, are designing IoT-enabled products, such as a smart lunchbox with temperature controls and parental alerts, and potted plants that use LED lights to alert users to light or water needs.

Kansas City School District Embraces IoT

go.nmc.org/aero

Olathe Public Schools in Kansas City, Missouri, have integrated high-grade wireless internet access to help teachers efficiently manage their classrooms and deliver blended learning curriculum. Teachers can take attendance wirelessly, while students across several middle schools recently collaborated on designing wind turbines using wireless-enabled devices.

Students Use the Internet of Things, Big Data, and Big Ideas to Build Smarter Cities

go.nmc.org/scit

Through the Moonshot program, a senior engineer at Google works with K–12 students to develop new ideas for smart-city initiatives. Learners use design thinking to explore solutions powered by the IoT to address transportation challenges, climate change, and resource scarcity.

For Further Reading

The following articles and resources are recommended for those who wish to learn more about the Internet of Things:

The Internet of Things Connectivity Binge: What Are the Implications?

go.nmc.org/impl

(Lee Rainie, Janna Anderson, Pew Research Center, 6 June 2017.) While increased connectivity means safety and security vulnerabilities, the Internet of Things continues its expansion. This article explores the possible outcomes of an inevitably connected world.

New Research Center Envisions the Internet of Things Applied to Personalized Learning

go.nmc.org/iotusc

(Ross Brenneman, USC Rossier School of Education, 21 October 2016.) At the University of Southern California, the Center for Human-Applied Reasoning and the Internet of Things (CHARIOT) brings together scholars from engineering and education disciplines. The center's work will focus on using IoT technology to gather K–12 student data to personalize instruction methods and provide learners and teachers with insights into student progress.

The Promise and Pitfalls of the Internet of Things in Canada

go.nmc.org/iotcan

(Public Policy Forum, 16 December 2016.) Fueled by applications of the IoT, Canada will require more skilled workers who can understand and interpret big data. This report recommends that education institutions partner with industry to provide optimal learning opportunities.

Methodology

The process used to research and create the *NMC/CoSN Horizon Report: 2017 K–12 Edition* is rooted in the methods used across all of the research conducted within the NMC Horizon Project. All editions of the *NMC Horizon Report* are informed by both primary and secondary research. Dozens of meaningful trends, challenges, and important developments in technology are examined for possible inclusion in the report for each edition before the expert panel selects the 18 topics profiled here.

Every report draws on the expertise of an international expert panel that first considers a broad set of trends, challenges, and developments in technology and then explores each of them in progressively more detail, reducing the set until the final listing of topics is selected. This process takes place online, where it is captured in the NMC Horizon Project workspace. The workspace is intended to be a completely transparent window into the work of the project, one that not only provides a real-time view of the work as it happens, but also contains the entire record of the process for each of the various editions published since 2006. The workspace used for the *NMC/CoSN Horizon Report: 2017 K–12 Edition* can be found at go.nmc.org/2017-k12-workspace.

This year, the panel was composed of 61 education and technology experts representing 20 countries across six continents; their names and affiliations are listed at the end of this report. Despite their diversity of backgrounds and experience, they share a consensus view that each of the profiled topics will have a significant impact on the practice of K–12 education around the globe over the next five years.

The procedure for selecting the topics in the report is based on a modified Delphi process refined over the now 15 years of producing the *NMC Horizon Report* series, and it began with the assembly of the panel. The panel represents a wide range of backgrounds, yet each member brings a relevant expertise. Over the years of the NMC Horizon Project research, more than 2,000 internationally recognized practitioners and experts have participated on the panels; in any given year, a third of panel members are new, ensuring a flow of fresh perspectives. Nominations to serve on the expert panel are encouraged and can be submitted at go.nmc.org/panel.

Once the panel for a particular edition is constituted, the members' work begins with a systematic review of the literature — press clippings, reports, essays, and other materials — that pertains to technology developments, trends and challenges, current research and reports, and more. Panelists are provided with an extensive set of background materials when the project begins and are then asked to comment on them, identify those that seem especially worthwhile, and add to the set.

Following the review of the literature, the expert panel engages in the central focus of the process — the research questions that are at the core of the NMC Horizon Project. The group discusses existing applications and manifestations of trends, challenges, and technology developments while also brainstorming new ones. A key criterion for the inclusion of a topic in this edition is its potential relevance to teaching, learning, and creative inquiry in higher education.

These research questions are designed to elicit a comprehensive listing of interesting technology developments, challenges, and trends from the panel:

1 Which of the important developments in educational technology catalogued in the NMC Horizon Project list will be most important to teaching, learning, or creative inquiry for K–12 education within the next five years?

2 What important developments in educational technology are missing from our list? Consider these related questions:

- > **What would you list among the established developments in technology that some schools are using today that arguably *all* schools should be using broadly to support or enhance teaching, learning, or creative inquiry?**
- > **What technologies that have a solid user base in consumer, entertainment, or other industries should schools be actively looking for ways to apply?**
- > **What are the developments in technology you see advancing to the point that schools should begin to take notice during the next four to five years?**

3 What key trends do you expect to accelerate educational technology uptake in K–12 education?

4 What do you see as the significant challenges impeding educational technology uptake in K–12 education during the next five years?

In the first step of this approach, the responses to the research questions are systematically ranked and placed into adoption horizons by each expert panel member using a multi-vote system that allows members to weight and categorize their selections. These are compiled into a collective ranking, and inevitably, the ones around which there is the most agreement are quickly apparent.

From the comprehensive list of trends, challenges, and developments in technology originally considered for any report, the dozen that emerge at the top of the initial ranking process in each area are further researched and expanded. Once these interim results are identified, the group explores the ways in which these topics impact teaching and learning in schools. A significant amount of time is spent researching real and potential applications for each of the topics that would be of interest to practitioners. The semi-finalist topics of the interim results are then ranked yet again. The final topics selected by this year's expert panel are those detailed here in the *NMC/CoSN Horizon Report: 2017 K–12 Edition*.

The 2017 K–12 Edition Expert Panel

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Alex Freeman
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Helen Crompton
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Gordon Dahlby
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Gavin Dykes
Education World Forum
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Christine Evelyn
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Claus Gregersen
Herning Gymnasium
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Norton Gusky
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Lisa Gustinelli
Palm Beach State College
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British School Jakarta
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Tony Inglese
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Jan Morrison
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Kieran O'Connor
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United States

Brandon Olszewski
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Len Scrogan
University of Colorado–Denver
United States

Jeremy Shorr
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Daniela Silva
Qatar Foundation Schools
Qatar

Morten Sjøby
Norwegian Centre for ICT in
Education
Norway

Nada Stojičević
Elektrotehnička škola “Nikola Tesla”
Serbia

Kari Stubbs
BrainPOP
United States

Nancy Sturm
The Sextant Group
United States

Christine Tomasik
C.L. Tomasik Education
United States

Michael van Wetering
Hippasus
United States

Malte von Sehested
Gyldendal
Denmark

Endnotes

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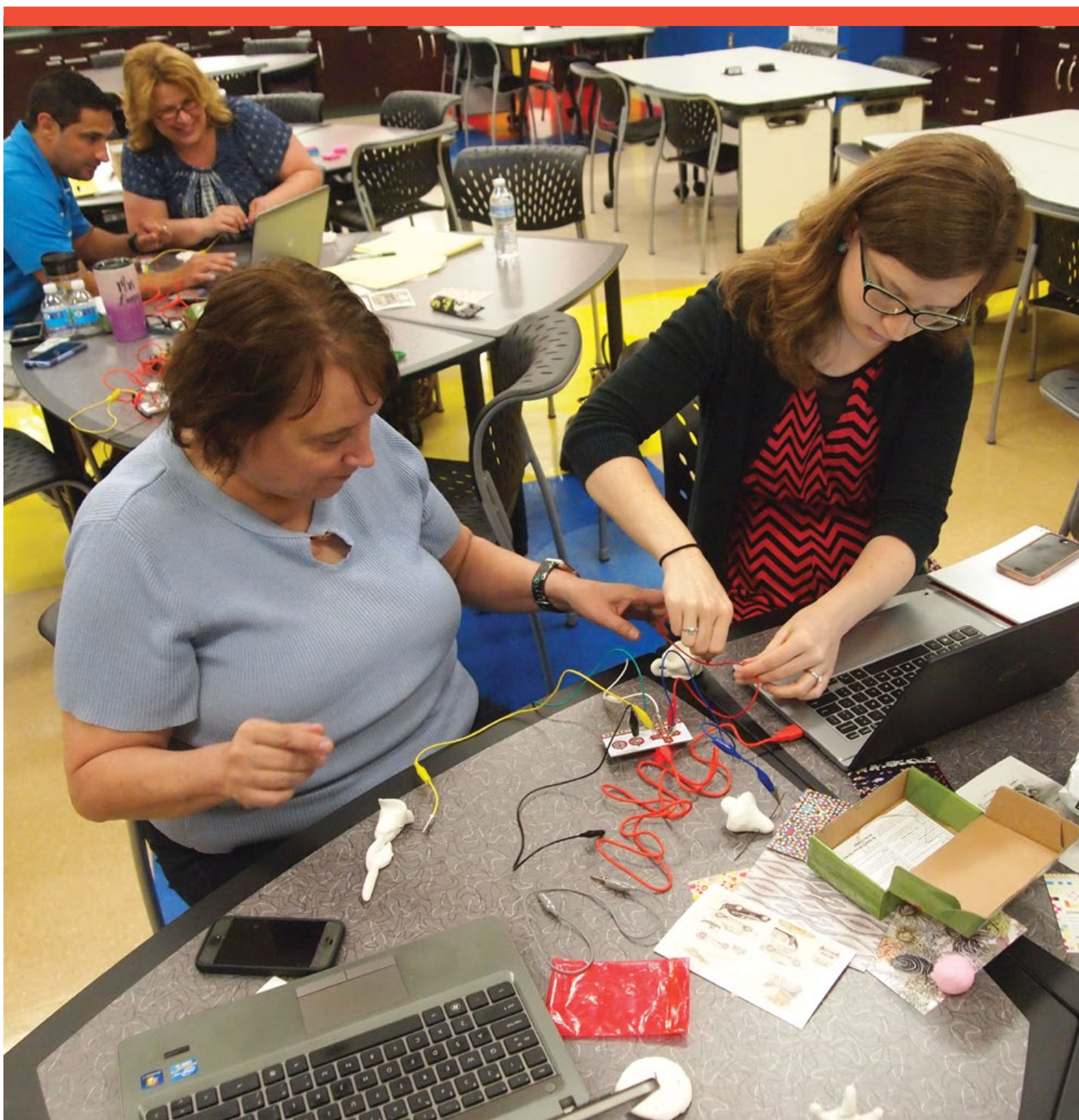
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