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LEADING EDUCATION INNOVATION

NMC/CoSN Horizon Report > 2016 K-12 Edition

The *NMC/CoSN Horizon Report: 2016 K-12 Edition* examines emerging technologies for their potential impact on and use in teaching, learning, and creative inquiry in schools.

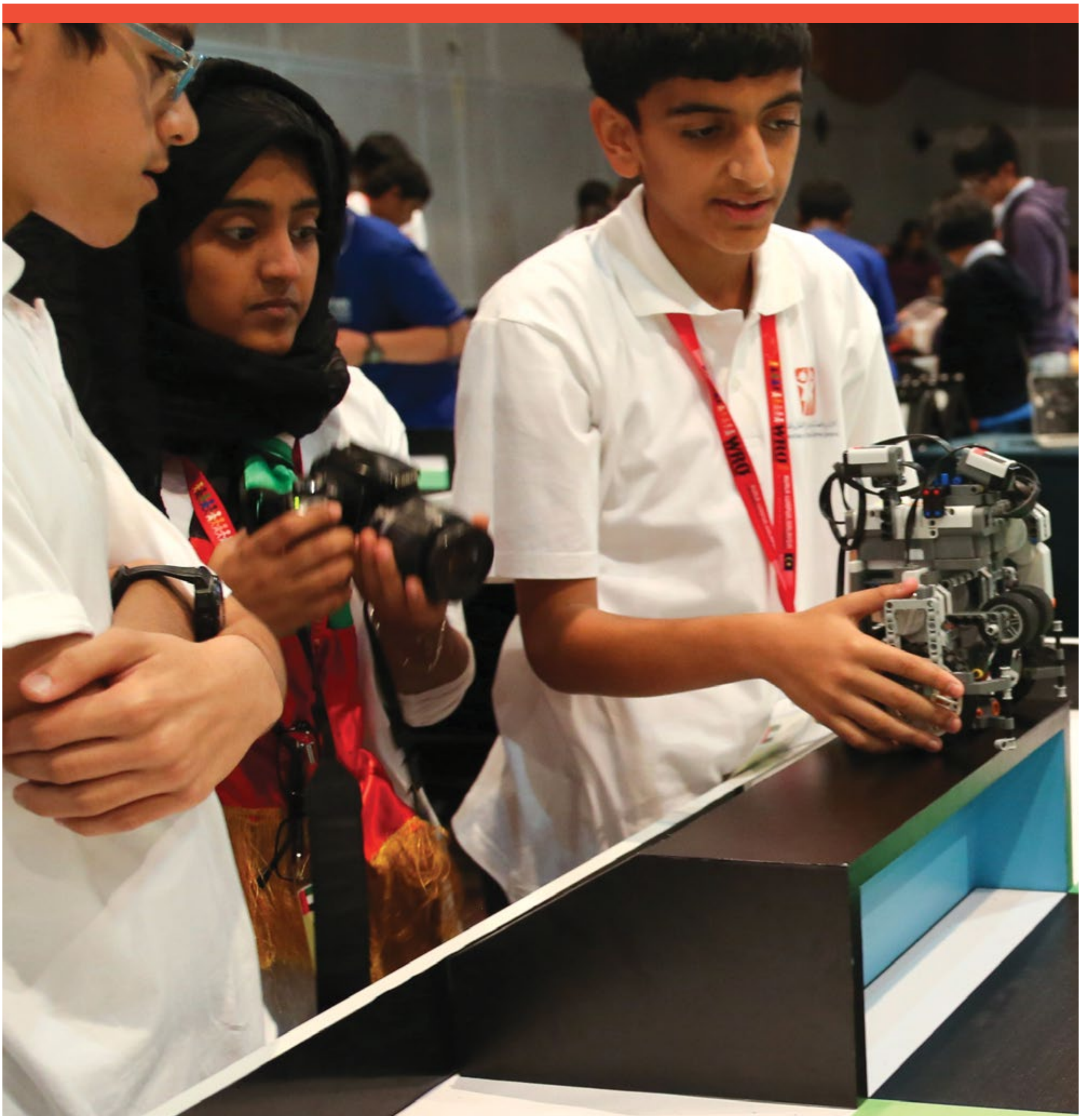

Table of Contents

> Click on a topic to jump to that page.

The *NMC/CoSN Horizon Report: 2016 K-12 Edition*
is a collaboration between The NEW MEDIA CONSORTIUM and
The CONSORTIUM for SCHOOL NETWORKING.

The research behind the *NMC/CoSN Horizon Report: 2016 K-12 Edition* is jointly conducted by the New Media Consortium (NMC) and the Consortium for School Networking (CoSN) and made possible by Share Fair Nation under a grant from the Morgridge Family Foundation. CoSN and Share Fair Nation's critical participation in the production of this report and their strong support for the NMC Horizon Project are gratefully acknowledged. To learn more about the NMC, visit nmc.org; to learn more about CoSN, visit cosn.org; to learn more about Share Fair Nation, visit sharefairnation.org.

ISBN 978-0-9977215-1-5

Citation
Adams Becker, S., Freeman, A., Giesinger Hall, C., Cummins, M., and Yuhnke, B. (2016). *NMC/CoSN Horizon Report: 2016 K-12 Edition*. Austin, Texas: The New Media Consortium.

Cover Photography
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Executive Summary

What is on the five-year horizon for K-12 schools worldwide? Which trends and technologies will drive educational change? What are the challenges that we consider as solvable or difficult to overcome, and how can we strategize effective solutions? These questions and similar inquiries regarding technology adoption and transforming teaching and learning steered the collaborative research and discussions of a body of 59 experts to produce the *NMC/CoSN Horizon Report: 2016 K-12 Edition*, in partnership with the Consortium for School Networking (CoSN) and made possible by Share Fair Nation under a grant from the Morgridge Family Foundation.

This publication charts the five-year horizon for the impact of emerging technologies in school communities across the globe. With 15 years of research and publications, the NMC Horizon Project can be regarded as the world's longest-running exploration of emerging technology trends and uptake in education. In partnership with CoSN this year, a companion toolkit known as the *Horizon Report Digital Toolkit: 2016 K-12 Edition* was created to encourage discussions around these findings in local communities and help practitioners implement the ideas in this report.

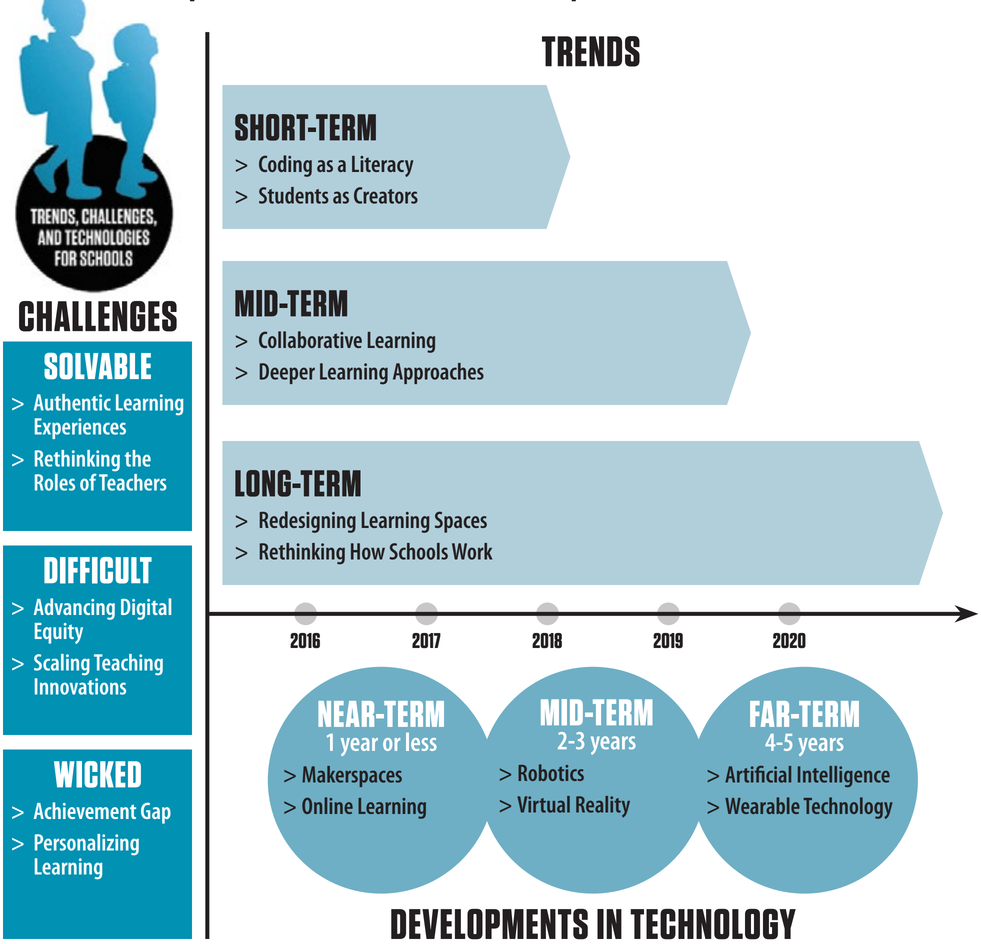
The experts agreed on two long-term trends: redesigning learning spaces to accommodate more immersive, hands-on activities, as well as rethinking how schools work in order to keep pace with the demands of the 21st century workforce and equip students with future-focused skills. In the short-term, the rise of coding as a literacy emerged as a new trend this year. As the number of computer science jobs are expected to proliferate in the next five years, there is a need for students to learn coding and programming skills, which have proven to bolster problem-solving, creativity, and critical thinking skills. These are just three of the 18 topics analyzed in the *NMC/CoSN Horizon Report: 2016 K-12 Edition*, indicating the key trends, significant challenges, and important technological developments that are very likely to impact changes in K-12 education across the world over the next five years.

Regarding the challenges for schools, creating more authentic learning opportunities and reconfiguring the roles of teachers is considered solvable. K-12 leaders are already addressing the former problem by partnering with local businesses to provide real-world experiences for students and expose them to different careers at a young age. When it comes to evolving expectations for teachers, both pre-service training and professional development are emphasizing creative technology use and scenarios where they transition from lecturers to guides and coaches. On the other hand, the experts identified the task of bridging the achievement gap as a wicked challenge — one that is seemingly impossible to define let alone solve. Even in the face of increasingly advanced technologies and quality learning materials, not every demographic has the same level of access, and learning outcomes are still unequal throughout the world.

In view of the trends and challenges observed, the panel also signalled the important developments in technology that could support these drivers of innovation and change. Makerspaces and online learning are both expected to be widely adopted by schools in one year's time or less to encourage students to take ownership of their education by creating and provide them with ubiquitous access to digital tools, discussion forums, rich media, and more. The time-to-adoption for robotics and virtual reality are estimated within two to three years, while artificial intelligence and wearable technology are expected to be mainstream in schools within four to five years.

The three key sections of this report constitute a reference and straightforward technology planning guide for educators, school leaders, administrators, policymakers, and technologists. It is the NMC and CoSN's hope that this research will help to inform the choices that institutions are making about technology to improve, support, or extend teaching, learning, and creative inquiry in K-12 education across the globe. Education leaders worldwide look to the NMC Horizon Project and both its global and regional reports as key strategic technology planning references, and it is for that purpose that the *NMC/CoSN Horizon Report: 2016 K-12 Edition* is presented.

Topics from the *NMC/CoSN Horizon Report: 2016 K-12 Edition*



Introduction

The *NMC/CoSN Horizon Report: 2016 K-12 Edition* was produced by the NMC in collaboration with CoSN, and made possible by Share Fair Nation under a grant from the Morgridge Family Foundation. The internationally recognized *NMC Horizon Report* series and regional NMC Technology Outlooks are part of the NMC Horizon Project, a comprehensive effort established in 2002 by the NMC that identifies and describes important developments in technology likely to have a large impact over the coming five years 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 developments in technology or digital strategies that are likely to enter mainstream use within their focus sectors over the next five years. Key trends and challenges that will affect current practice over the same period frame these discussions.

In the pages that follow, 18 topics carefully selected by the 2016 K-12 Edition Expert Panel related to the educational applications of technology are examined, all of them areas very likely to impact technology planning and decision-making over the next five years (2016-2020). Six key trends, six significant challenges, and six important developments in educational technology are placed directly in the context of their likely impact on the core missions of schools, and detailed in succinct, non-technical, and unbiased presentations.

The report's first two sections focus on an analysis of trends driving technology decision-making and planning, and the challenges likely to impede the adoption of new technology developments, respectively. Each includes an explicit discussion of the trend or challenge's implications for policy, leadership, and practice in schools, along with examples and relevant readings.

The third section, in which six important developments in educational technology are described, is ultimately framed by these trends and challenges. The adoption or abandonment of these technologies by schools will be very much determined by the responses taken across the world to these drivers of and obstacles to innovation and change. Each topic closes with an annotated list of suggested readings and additional examples that expand on the discussion in the report.

Six key trends, six significant challenges, and six important developments in educational technology are placed directly in the context of their likely impact on the core missions of schools.

The process used to research and create the *NMC/CoSN Horizon Report: 2016 K-12 Edition* is rooted in the methods used across all 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.

Every report draws on the considerable expertise of an international expert panel that first considers a broad set of important trends, challenges, and developments in educational technology, and then examines each of them in progressively more detail, reducing the set until the final listing of trends, challenges, and technologies is selected. This process takes place online, where it is captured in the NMC Horizon Project wiki. The wiki 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 wiki used for the *NMC/CoSN Horizon Report: 2016 K-12 Edition* can be found at k12.wiki.nmc.org.

The panel was composed of 59 education and technology experts from 18 countries on six continents this year; 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 panel was composed of 59 education and technology experts from 18 countries on six continents this year.

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 began with the assembly of the panel. The panel represents a wide range of backgrounds, nationalities, and interests, yet each member brings a relevant expertise. Over the decade of the NMC Horizon Project research, more than 1,500 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 each year. Nominations to serve on the expert panel are encouraged; see go.nmc.org/panel.

Once the panel for a particular edition is constituted, their work begins with a systematic review of the literature — press clippings, reports, essays, and other materials — that pertains to emerging technology. Members 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. The group discusses existing applications of emerging technology and brainstorms 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 K-12 education. A carefully selected set of RSS feeds from hundreds of relevant publications ensures that background resources stay current as the project progresses. They are used to inform the thinking of the participants.

Following the review of the literature, the expert panel engages in the central focus of the research — the research questions that are at the core of the NMC Horizon Project. These questions were designed to elicit a comprehensive listing of interesting technologies, challenges, and trends from the panel:

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

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

- **> What would you list among the established developments in educational 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 technologies that you see developing 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 over the next five years?

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 educational 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 the expert panel are those detailed here in the *NMC/CoSN Horizon Report: 2016 K-12 Edition*.

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 impacting 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, 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 k12.wiki.nmc.org/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.

Policy. While all of the identified trends had policy implications, two trends in particular are expected to have a strong impact on policy decisions in the next five years. Governments all over the world are contributing to the long-term re-envisioning of schools with policies that promote competency-based learning, 21st century skill acquisition, and workforce readiness. Finland's National Curriculum, for example, is replacing traditional classes such as history and mathematics with interdisciplinary classes that remove the perceived silos between subjects to provide students with a broader perspective and hands-on vocational training.[1]

Likewise, the expert panel believes that the integration of coding as a new form of digital literacy is currently on the rise in schools in the short-term, due to its significant role in imparting computer science skills in learners. The US government has prioritized coding and programming with $4 billion of funding for the Computer Science for All initiative. Teachers across the country will benefit from professional development, with $100 million of the budget allocated to districts for training programs. The initiative also aims to provide access to underserved student populations whose exposure to coding and computer science has been extremely limited.[2]

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.

Leadership. While there are leadership implications for all the identified trends that are discussed in the following pages, two trends stand out as unique opportunities for vision and leadership. Collaborative learning is increasingly materializing in curricula and classroom activities, but K-12 leaders see this mid-term development as an opportunity to evolve school philosophies, embedding the spirit of teamwork and cooperation deeply into school cultures. In Massachusetts, University Park Campus School has modeled this shift, developing an initiative where students are introduced to collaborative approaches in middle school and then progress to high school, where they direct their own team projects with minimal teacher intervention.[3]

As more schools embrace the notion of students as creators rather than merely passive consumers of knowledge, leading education organizations are devising strategies that empower student-driven media production and invention. With a network of 60+ schools across the US, Big Picture Learning has developed programs in which students plan their own curricula based on their unique passions and interests. They work with teachers, advisors, and peers on yearlong projects focused on designing a product from start to finish.[4]

Practice. Each of the six trends identified by the expert panel has numerous implications for teaching and learning practice, and current examples are easy to find. The panel of experts identified the redesign of physical learning spaces, highlighted as one of two developing long-term trends in the following pages, as crucial for nurturing 21st century learning opportunities. The layout of a classroom, along with the furniture and technology it contains, has proven to impact student engagement and performance, and schools are increasingly experimenting with novel arrangements. Innova, a school system in Peru, encompasses buildings that are completely flexible, including mobile furniture and equipment that can be customized for each class to promote student-centered learning.[5]

All over the world, schools are prioritizing deeper learning approaches that favor real-world experiences to better prepare students for the workforce. These strategies often involve projects in which students are solving a local or global challenge, contributing to the community even while still in school. A fifth-grade class in South Korea engaged in an active problem-solving activity when a local playground was turned into a parking lot; students went through the entire process of planning a new location for the playground, pursuing approval from local authorities, familiarizing themselves with safety codes, and raising money to build it.[6]

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

Redesigning Learning Spaces

Long-Term Trend: Driving EdTech adoption in K-12 education for five or more 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 in them. Education has traditionally relied on teacher-centric approaches where lectures were the main source for knowledge transference.[7] 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. Additionally, innovative thinking in architecture and space planning is influencing the sustainable design and construction of new school infrastructures that have the potential to significantly impact classroom practices and student learning.[8]

Overview

In the United States, over $2 trillion has been spent on school construction where most classrooms employ a more than 100-year-old model that consists of desks positioned in rows and teachers at the front of the room. Despite many of these buildings being decades old, often they have not undergone any significant redesigns.[9] Schools and districts face challenging decisions about the future of their aging infrastructures, spurring a desire to learn more about how classroom designs can be applied to foster positive learning outcomes and to develop innovative and efficient models.[10] A study at the University of Washington found that simple adjustments to classroom environments such as lighting, temperature, and decoration affect academic performance.[11] Additionally, there has been increased attention in leveraging advancements in architectural design and construction to update and replace older buildings with more sustainable solutions.

Several topics throughout this report acknowledge the movement toward student-centered and collaborative learning, especially when enhanced by technology. A study conducted by the University of Melbourne indicates that students' academic achievement increases by 15% when transitioned from traditional classrooms to redesigned rooms with a focus on pedagogy and layout.[12] Classroom technologies have also evolved, and rooms once meant for desks, chairs, and chalkboards must now accommodate hardware and connectivity to promote interactivity.[13] More flexible learning environments contain moveable furniture and technology that enable active learning, which has been shown to change the behaviors of students and teachers and improve student learning.[14] A study conducted at the University of Minnesota observed an instructor teaching two versions of the same class, one in an active learning classroom and the other in a traditional lecture setting. Researchers observed 48% more discussions and 22% less lecturing in the active learning classrooms, and participating students with much lower ACT scores overcame the achievement gap to earn the same average grade as students in the traditional lecture setting.

Schools and districts are also investigating methods to construct buildings and design classrooms that factor in economic viability, environmental consciousness, and social awareness. Green schools use 33% less energy and 32% less water than traditional schools; if all new schools were built using green standards, $20 billion would be saved in energy costs over the next ten years.[15] The environmental design of schools can also impact students; a study by Pacific Gas and Electric indicated that students in classrooms with more natural light advanced 20% more quickly in mathematics and 26% in reading.[16] Another study at the National University of Malaysia concluded that simply providing more daylight into a classroom will improve a student's overall health, well-being, and academic performance.[17] According to the US Environmental Protection Agency, healthy air quality in schools can increase test scores and impact student performance.[18]

Implications for Policy, Leadership, or Practice

The New Zealand Ministry of Education is embracing policy changes in a major effort to transform the country's school spaces based on the finding that student learning is maximized when it is self-led, collaborative, and social.[19] The Ministry, as part of their legal and design standards, has published a set of guidelines and an assessment tool to help schools apply flexible learning spaces into redesigns and new constructions.[20] All schools are required to comply with these standards and incorporate them into their ten-year plans.[21] The New South Wales Department of Education has embarked on a significant initiative to advance its learning environments to better accommodate the needs of their 21st century students with greater flexibility, collaboration, and technology integration.[22] Along with $2.7 billion from the federal government, the state has contributed $1 billion to create 1,600 new or refurbished learning spaces. Currently, students and teachers are testing prototype spaces that include flexible furniture at the Department's Futures Learning Unit in Sydney with the first new school to be completed by 2019 in Parramatta.[23]

Research has begun to surface the merits of successful implementations of revamped pedagogies and spaces. The Learning Environments Applied Research Network (LEaRN) was established as an international forum facilitating education and industry to study and envision physical learning environments.[24] LEaRN's initiatives vary from studying learning spaces in schools to the value of hospital corridors as informal learning environments. In a similar effort, the Evaluation of 21st Century Learning Environments is developing three multidisciplinary evaluation frameworks for learning spaces. The frameworks will inspire the design and use of learning environments to support the connections of curriculum, pedagogy, physical and virtual space, as well as the alignment of other variables that affect students' educational experiences.[25]

Successful exemplars of modern spatial design are accommodating the needs of 21st century learners. The Ørestad Gymnasium in Denmark is a 1,000-student high school that encompasses one large, open classroom, designed to nurture creativity and collaboration and to prepare students with future-focused skills. Half of students' time is spent with teachers and the other half is spent in student-led learning through makeshift classrooms with moveable walls and furniture.[26] Innova, a revolutionary school system in Peru, has built a network of 29 schools supporting 20,000 students with ambitious student-centered curricula that inspire self-discovery and the use of technology.[27] Teachers participate in an extensive training program to learn how to successfully integrate various active and project-based pedagogies into their curriculum. All buildings are completely flexible, with mobile furniture and equipment to ensure that spaces can be customized for each class.

For Further Reading

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

3 Ways Mobile Technology Is Transforming Learning Spaces
go.nmc.org/mobilespace
(Dennis Pierce, *THE Journal*, 25 August 2015.) The introduction of mobile technology into the classroom is redefining how the space can be used, including its ability to enable learning anywhere, bolster individual creativity, and untether teachers from cumbersome equipment.

Creative Learning Spaces
go.nmc.org/steele
(Steele High School, 26 July 2016.) High school students in Amherst, Ohio will soon be able to use the Creative Learning Space, which integrates technology more seamlessly into classrooms to encourage collaboration and active learning.

Green Schools Curriculum Centers STEM Learning on Sustainability
go.nmc.org/greensch
(Andrea Korte, American Association for the Advancement of Science, 19 January 2016.) The Green Schools Energy Curriculum is leveraging data gathered by incorporating green-technologies on campus to help middle school students make connections between STEM education and environmentally-conscious energy consumption.

How Innovative Design is Changing the Educational Landscape
go.nmc.org/indesign
(Brett Henebery, *The Educator*, 9 June 2016.) A primary school in Australia has been recognized for the redesign of its facility into a "sticky model," where students' advancement through the school's design coincides with their projects' progress and development.

The How and Why Behind Our Innovative Learning Space
go.nmc.org/howandwhy
(Sam Gibson, *Tomorrow's Learners*, 18 July 2015.) A secondary school in New Zealand remodeled their facility to create more cooperative learning spaces, including a technology hub equipped with computers that students can access throughout the day.

The Rise of Educational Escape Rooms
go.nmc.org/escape
(Zara Stone, *The Atlantic*, 28 July 2015.) The concept of escape rooms has been a novel advent in the consumer sector, and some teachers are finding value in its blend of gamification, critical thinking, and teamwork.

Rethinking How Schools Work

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

There is a focused movement to reinvent the traditional classroom paradigm and rearrange the entire school experience — a trend that is largely being driven by the influence of innovative learning approaches. Methods such as project-,[28] competency-,[29] and challenge-based learning[30] call for school structures that enable students to move from one learning activity to another more organically, removing the limitations of bell schedules. The multidisciplinary nature of these contemporary approaches has popularized creative applications of technology and fostered innovative school models that link subject matter to the real world. As learning becomes more fluid and student-centered, K-12 leaders believe that schedules should be more flexible, allowing opportunities for authentic learning and ample room for independent study.[31] Also driving this trend is the notion that public, private, and charter schools are no longer the sole options; unconventional models including open, virtual, and project-based learning schools are expanding possibilities for formal education.

Overview

The overly regimented learning of traditional schools is being eclipsed by the recognition that formal education should mirror the way people learn and work in the 21st century. Previous generations operated with preset trajectories, planning to spend their entire careers in the same field, often at the same company.[32] In this antiquated picture, school revolved around preparing students for a prescribed set of pathways; however, current workforce trends demand changes to schooling. Today, LinkedIn reports that on average, people change jobs four times before turning 32 years old.[33] The latest crop of students is characterized as entrepreneurial, global thinkers who are highly social, visual, and technological. They are early adopters of digital tools, social media influencers, and hyper aware of world issues such as climate change.[34] School leaders are acknowledging that sitting all day in rows of desks, studying one disparate subject after another is counterintuitive to contemporary learners.[35] In recent years, many K-12 pillars have been called into question, including grading systems, consecutive six-hour schedules, and homework.

Futurists have also identified a number of related developments that will disrupt traditional schooling. *Fast Company* recently crowdsourced insights from innovative education companies to surface the most significant changes to come in the next five years, including the growth of remote interaction. While students communicating with each other regardless of location is not new, its impact on public schools has been glacial; advancements in information and communications technology (ICT) and social networks make it easier than ever for students to connect with and learn from renowned authors, scientists, and other experts outside of the building. Another major shift is occurring around how mastery is perceived. Rather than measuring learning in credit hours and grade point averages, K-12 leaders are beginning to pilot competency-based models that certify the mastery of specific skills through students' active demonstration of knowledge in real-world scenarios.[36]

Education leaders looking for successful alternative models to adopt can look to Nordic school systems. In addition to fostering more equitable conditions for students, schools in Denmark, Finland, Norway, and Sweden have been pioneers of emerging technology and 1:1 programs.[37] With no national curriculum mandated, schools are decidedly more agile and student-centered, creatively leveraging technology to cultivate more engaged and active learning. For example, Kunskapshubben, a publishing platform built and hosted by Swedish school Årstaskolan, allows teachers to post instructional videos and students to upload completed assignments.[38] In the US, a growing number of schools are breaking from traditional models to create more student-centered models, including High Tech High, where teachers and students co-design a curriculum around solving real-world problems.[39] Facebook recently partnered with Summit Public Schools, a nonprofit charter school network in Silicon Valley, to launch a free student-directed learning system in which students choose their projects and set their own pace.[40]

Implications for Policy, Leadership, or Practice

Given the country's reputation for having one of the world's best education systems, Finland has made significant progress in devising policies that revamp K-12 schooling. Their National Curriculum Framework requires a certain number of schools' traditional subject-based classes like history and math to be replaced with interdisciplinary classes based on broader topics, such as the EU or vocation-specific lessons.[41] On a local level, individual schools and districts are rethinking their grading polices. Fairfax County Schools in Maryland, for example, do not allow homework assignments to count for more than 10% of students' grades and Virginia's Prince George County Public Schools do not factor in attendance.[42] *The Washington Post* reports that an increasing number of schools in the US are discouraging and even prohibiting teachers from giving out scores of zero and are providing more flexible opportunities for students to redo assignments and retake exams they failed.[43]

Implementing new models of education at scale necessitates sufficient leadership and support networks. A group of educators in Asia has founded an active learning approach called AMPed, which requires students to pursue their learning with purpose. Student projects include a wide range of experimental, aerial, and craft-based activities.[44] Many international schools across the continent have used the International School of Beijing (ISB) Futures Academy as a model for a school designed around experiential learning. All subjects at ISB are integrated, teachers act as facilitators who provide resources, and learning spaces are open and flexible.[45] Funding is also vital for advancing this long-term trend. Education startup incubator 4.0 Schools has launched two experimental school designs in New Orleans including Rooted School, a high school that seeks to prepare students for available high-growth, high-wage jobs in their area.[46]

New models are being envisioned to better facilitate independent study and creative inquiry, particularly for at-risk learners. New York's Bronx Arena High School is catering to around 200 high-need students by eradicating formal classes altogether, instead emphasizing self-guided learning.[47] Students engage in different activities based on personal interests, each developing core competencies that mirror real work environments. Four hours every day are devoted to students situated in arenas, groups of 25 learners, moving through a tailored online curriculum. Teachers provide mini-lessons and help each learner set and accomplish unique goals. Much of the self-paced work focuses on creating; for example, one student designed a game comparing monarchies to democratic republics while another crafted a presentation on various presidential candidates' stances on abortion. Similarly, the agile classroom design at Connecticut's Fairchild Wheeler Interdistrict Magnet Campus resembles a Silicon Valley workspace and represents a shift from a traditional lecture-centered model to collaborative learning.[48]

For Further Reading

The following resources are recommended for those who wish to learn more about rethinking how schools work:

Improving Schools Through Design Thinking
go.nmc.org/desthink
(Thomas Riddle, *Edutopia*, 3 February 2016.) The five stages of design thinking — empathize, define, ideate, prototype, and test — have compelling applications for classrooms as they enable students to be creative and concretely demonstrate their newly acquired skills.

Is Competency-Based Education Worth the Investment?
go.nmc.org/iscbe
(Fiona Hollands, *EdSurge*, 9 May 2016.) An *EdSurge* columnist discusses the different ways in which competency-based education is materializing at institutions as well as the challenges hindering more widespread uptake and success.

Setting an Agile School Rhythm
go.nmc.org/rhyth
(Doug Belshaw, *DML Central*, 13 July 2015.) The author explores how the Kanban system can help teachers to better plan learning programs and how mimicking the agile scrum model in a classroom setting can inspire students to take ownership over their progress.

Virtual Charter Schools Need "Bold Action" for Change, Says National Charter School Advocacy Group
go.nmc.org/boldac
(Jamie Martines, *The Hechinger Report*, 16 June 2016.) In response to several poorly performing virtual charter schools, the National Alliance for Public Charter Schools recently issued a call to action to state policymakers to revise the way they are governed.

We Need An Education System That Excites Children
go.nmc.org/excites
(Andy Powell, *Teaching Times*, accessed 25 July 2016.) The CEO of an independent education foundation believes there is no reason for a top-down, one-size-fits-all school model. He outlines the six steps for change, which include replacing standardized testing with individual profiles of attainment and conducting vocational training in specialist facilities.

Why We Must — and Can — Restore Safe & Healthy School Hours
go.nmc.org/whychange
(Start School Later, accessed 25 July 2016.) Start School Later is an organization that advocates for schools to update their hours based on evidence that adolescents have a more difficult time falling asleep early than children and adults.

Collaborative Learning

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

Collaborative learning, which refers to students or teachers working together in peer-to-peer or group activities, is based on the perspective that learning is a social construct.[49] The approach involves activities that are generally focused around four principles: placing the learner at the center, emphasizing interaction, working in groups, and developing solutions to real problems. Collaborative learning models are proving successful in improving student engagement and achievement, especially for disadvantaged students. Educators also benefit through peer groups as they participate in professional development and interdisciplinary teaching.[50] An added dimension to this trend is an increasing focus on global online collaboration where digital tools are used to support interactions around curricular objectives and promote intercultural understanding.[51] For example, students and teachers in New Zealand and Singapore are using platforms such as WhatsApp to establish an online partnership to bring forth a greater understanding and perspective of the importance of each culture to one another.[52]

Overview

Collaborative learning, also commonly referred to as cooperative learning, is becoming more pervasive in schools and classrooms throughout the world, with technology as a significant enabler.[53] A recent report by The World Economic Forum indicates that contemporary technologies are expanding the reach of cooperative learning strategies by furthering the communication and collaboration competencies that affect how students approach complex challenges.[54] Technology empowers teachers to assemble global communities of practice and allows students to collaborate with each other, regardless of physical location.[55] While collaborative learning has garnered traction, it is important to remain diligent when developing strategies. Collaborative approaches are social in nature and tend to highlight extroverted qualities while placing a strain on inward thinking individuals.[56] Student learning is optimized when experiencing a blend of cooperative and individual work.[57]

Successful collaborative learning strategies encourage increased student achievement, discussion, confidence, and active learning.[58] This has especially been the case throughout the Asia Pacific, where 17,000 students participated in Tournament of Minds, a competition in its 19th year focused on improving collaboration skills in science, technology, engineering, and math (STEM) disciplines.[59] The program evaluates students in teams working together without adult supervision to solve a problem in one of the four STEM subjects. The National Girls Collaborative Project (NGCP) has identified collaboration as a key driver in advancing the desires of girls to pursue careers in STEM.[60] NGCP has established "Collaboratives" throughout the US to expand and strengthen STEM awareness, serving nearly 25 million youth. Their series of mini-grants, events, and webinars has engaged over 66,000 professionals, researchers, and practitioners to collaborate and create partnerships furthering the mission.

When applied in the spirit of deeper collaboration, technology can unite students around big ideas and projects while integrating web-based resources that will expand their learning.[61] Digital tools are fundamental ingredients in the facilitation of collaborative learning approaches, offering platforms for communication and activities in synchronous and asynchronous environments.[62] A recent study by SMART Technologies has shown that collaborative learning strategies, paired well with technology, result in the greatest improvement in social and emotional skill development.[63] Cloud computing has been particularly lauded for its role in bolstering collaboration as it instills unlimited potential for teacher, student, and parent communication.[64] By using cloud-based collaboration tools from a common virtual location, such as Google Apps for Education, people can easily access and share learning materials with each other, making updates in real time.

Implications for Policy, Leadership, or Practice

A recent US policy brief, "Using Technology to Support At-Risk Students' Learning," suggests that the government and schools should prioritize technology implementations in schools that promote student engagement in authentic tasks and develop 21st century skills, including collaboration, and not those focused on remediation.[65] In Europe, a €14 billion effort from the European Commission known as Erasmus+ will provide opportunities for over four million people to acquire new knowledge and experiences abroad. The program aims to spur greater mobility and collaboration among European schools to provide high-quality learning experiences.[66] One Erasmus+ initiative is Collaborative Education Lab, a visionary collective from Austria, Belgium, Estonia, Ireland, Poland, and Portugal that plans to create extensive professional development opportunities around collaborative learning, make recommendations on effective collaborative teaching and learning in schools, and leverage evidence-based results to influence national and European policy.[67]

Leaders at University Park Campus School have embraced a strategy to cultivate a positive philosophy of collaboration within teachers and administration, which is seen by students and modeled in their work in the classroom.[68] This holistic cultural shift has been identified as the first step in building a collaborative culture committed to address various school challenges.[69] The initiative begins in middle school with introductions to collaboration and, by high school, teachers take a backseat as students direct their own collaborative work. Transforming a district or school into a cooperative environment can also ensure the development of curricula that continuously evolve teaching practices and improve student outcomes.[70] A team at Duke University is launching a professional development program that will provide elementary school teachers with training in consultation and collaboration to further language development in their classrooms.[71]

Innovative teachers have begun to explore new technologies for cooperative problem-solving. Researchers at Future University in Japan are investigating participant collaboration in virtual worlds as a medium for solving project-based tasks.[72] Using the scenario of dumping nuclear waste bins, participants program and maneuver virtual and real-world robots to accomplish desired tasks which, in turn, are examined for student learning, task complexity, and immersion. The Smithsonian recently released Learning Lab, a toolkit and collaborative community for teachers and students to develop, create, and share digital learning experiences and resource collections.[73] Resources like this ensure that teachers have timely information to guide them, especially as successful implementation in the classroom is dependent on students' attitudes and understanding of collaborative learning.[74] Collaborative digital tools will enable teachers to efficiently observe student groups and deliver feedback.[75]

For Further Reading

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

102 Free (Or Free-to-Try) Online Collaborative Learning Tools for Teachers and Educators
go.nmc.org/101collabtools
(*Docurated*, 16 February 2016.) This extensive list of online tools, organized by relevance to K-5, middle school, and high school teachers, can be used to enhance and facilitate collaborative learning environments.

Building Your Roadmap for 21st Century Learning Environments: A Planning Tool for Education Leaders
go.nmc.org/roadmap21
(Roadmap 21, accessed 1 July 2016.) Three organizations have collaborated to provide a set of tools to assist school leadership in the evolution of schools. The roadmap serves as a foundational guide that includes principles, key questions, action steps, policy considerations, and access to exemplars.

Inside the Collaborative Classroom: The Core Principles
go.nmc.org/collabcore
(Center for the Collaborative Classroom, 2015.) This whitepaper identifies and expands on four key threads that establish the foundation for a collaborative classroom model. The authors explore the relationship of social and academic curricula, fostering caring relationships and creating safe environments, student-centered learning, and the value of building on students' intrinsic motivations.

Large School Districts Come Together to Prioritize Sustainability
go.nmc.org/schoolsustainability
(Homeroom: The Official Blog of the US Department of Education, accessed 1 July 2016.) Twenty-one school districts throughout the US have formed a collaborative, representing 3.6 million children in 5,726 schools, to collectively "reduce their climate and ecological impact; connect their students to nature; and educate and engage their communities on climate and conservation."

Six Technologies that Will Affect K12 Education Over the Next 5 Years
go.nmc.org/sixtechnologies
(*Education Corner*, accessed 1 July 2016.) As the desire for collaboration skills in the workplace increases, schools are rethinking their learning spaces to facilitate more teamwork. This resource identifies six key collaboration technologies that will have an impact in the design of future learning spaces.

What We Know About Collaboration
go.nmc.org/collabweknow
(*Partnership for 21st Century Learning*, September 2015.) This brief, third in a four-part series on the "four C's," explores the facets and research of collaborative learning, evaluates its current state, and poses recommendations in order to present an accurate outlook of the landscape.

Deeper Learning Approaches

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

There is a growing 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.[76] In order to remain motivated, students need to be able to grasp how new knowledge and skills will impact the world around them. Pedagogical approaches that shift the dynamic from passive to active learning allow students to develop ideas themselves from new information and take control of how they engage with a subject.[77] These approaches include problem-based learning,[78] project-based learning,[79] challenge-based learning,[80] and inquiry-based learning,[81] which encourage creative problem-solving and actively implementing solutions. As the enabling role of technologies in learning crystalizes, educators are leveraging these tools to connect the curriculum with real-life applications.

Overview

The idea of deeper learning is not a new concept, but the technologies leveraged to support deeper learning pedagogies are continually evolving and can boost the quality, breadth, and reach of student work and collaborative projects. For example, social media platforms like Twitter are already being used by students both to discover new information and for publishing thoughts and ideas; educators have found that the same platforms can also connect students with local and global issues and allow them to explore and exchange perspectives.[82] Digital tools for content creation such as WeVideo provide easy methods to develop, edit, and present polished stories and content to the world.[83] Deeper learning approaches are often flexible and allow room for students to experiment with various technologies, platforms, and tools depending on what support they need for particular projects.[84]

Researchers from the University of Illinois at Urbana-Champaign recently examined the decision-making skills of students who participated in a project-based learning (PBL) activity compared to a group of students who received direct instruction using the same materials and a control group following standard curriculum. The study revealed that PBL students considered more than one side of a dilemma, used more comprehensive reasoning, and evaluated more frequently the importance of the assumptions underlying their decision-making. The researchers noted that the instructional materials were well-prepared in that students received prompts and structures for considering a variety of perspectives and counterarguments. Another defining characteristic of the PBL activity was that the students were addressing a real-life issue concerning the reintroduction and management of local wolves.[85]

Further, there is growing evidence suggesting that deeper learning approaches are more effective than traditional lecture-style models. The Education Policy Center at American Institutes for Research completed a three-year study focused on 19 high schools in 10 school networks that all shared an explicit, school-wide priority on providing opportunities for deeper learning with strategies including PBL, collaborative group work, internships, and longer-term assessment such as portfolios or exhibitions. In comparing the outcomes of the deeper learning network students with those of students outside these networks, deeper learning network schools were identified as producing better academic results, stronger interpersonal and intrapersonal skills, higher on-time graduation rates, and higher enrollment in four-year colleges. All students shared these positive results, regardless of their backgrounds or prior levels of achievement.[86]

Implications for Policy, Leadership, or Practice

Work is well underway across the world to develop policies that encourage deeper learning approaches in schools. According to Finland's National Core Curricula for pre-primary education and compulsory basic education, in autumn of 2016 all schools are expected to design and provide at least one multi-disciplinary, phenomenon- and project-based study-period per school year, in which all students have an opportunity to focus on studying topics of personal interest to them.[87] Phenomenon-based curriculum integrates different subjects and themes, crossing boundaries between them, so that students can study and think critically about real-world issues such as global warming or refugees.[88] The ENGAGE project, part of the EU's Science in Society agenda to promote more responsible research and innovation, is working to embed inquiry-based methods into schools across the EU. Students participate in scientific discovery and reflect on social and ethical implications by influencing policy on science education and providing recommendations for curriculum design.[89]

A number of organizations are providing support to schools to incorporate deeper learning. New Tech Network is working with over 100 schools, districts, and communities across the US and Australia to implement PBL in public schools and offer professional development in facilitating meaningful projects that require critical thinking, creativity, and communication.[90] Digital resources that enhance curriculum are also being created to support inquiry- and project-based learning that can be openly accessed from anywhere. Graduate education students at Harvard are developing an inquiry-based curriculum called EcoMUVE that leverages an immersive virtual ecosystem in which students become scientists, conducting research and collecting data from a variety of sources over time.[91] The EU's Go-Lab project, is another notable inquiry-based learning initiative providing a portal to hundreds of online laboratories as well as an authoring platform for educators and students to create personalized inquiry learning spaces to support their own experiments.[92]

Educators and schools can also learn from each other when it comes to implementing deeper learning methods and activities. A fifth-grade class in South Korea recently designed a playground for the children in their community after a local playground had been paved to use as a parking lot. The students used a variety of real-world transferable skills as they determined a location for the new playground, sought approval from appropriate authorities, designed the playground to meet local safety codes, plotted out locations for equipment, and procured funding.[93] Deeper learning often occurs when students are provided with greater flexibility and choice so that their passions can guide them. At Wildwood IB World Magnet School in Chicago, students create mind maps online based on questions they have related to new learning units; from their mind maps, they each choose an inquiry path to investigate. At the end of every unit they present their project or product at a fair open to parents, other teachers, and students.[94]

For Further Reading

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

10 Tips for Launching an Inquiry-Based Classroom
go.nmc.org/tentips
(Katrina Schwartz, *MindShift*, 21 September 2015.) This article provides tips for enhancing the inquiry-based classroom to allow students to formulate questions, make connections, and travel their own paths to reach a conclusion or develop a solution.

Building Inquiry in the 21st Century
go.nmc.org/building
(Christine Henke Mueller, *edstructure*, 29 August 2015.) An educator gives a detailed account of her journey implementing a passion-based learning approach in her classroom. While managing 42 different projects in one classroom can seem intimidating, benchmarks, workshops, and reflection activities can cultivate a well-organized structure that allows students to progressively meet their goals.

Deeper Learning
go.nmc.org/hewlett
(The William and Flora Hewlett Foundation, accessed 22 August 2016.) The Hewlett Foundation is a recognized authority on deeper learning. Their website is a hub for education professionals to learn more about deeper learning, including key programs and grants associated with the approach.

Developing a System of Micro-credentials: Supporting Deeper Learning in the Classroom
go.nmc.org/microcred
(Digital Promise, 2016.) Digital Promise has identified 40 micro-credentials that can be mapped to six indicators of evidence of engaging students in deeper learning. They aim to capture the key competencies that educators must develop to be effective facilitators.

Equal Opportunity for Deeper Learning
go.nmc.org/equop
(Pedro Noguera et al., Jobs for the Future, October 2015.) Jobs for the Future addresses how project- or problem-based learning can better prepare students for life after high school and implications for policy and practice.

How Deeper Learning Can Create a New Vision for Teaching
go.nmc.org/howdeeper
(Monica R. Martinez et al., National Commission on Teaching and America's Future, 2016.) This report provides examples and recommendations for educators seeking to adapt different approaches to support deeper learning outcomes based on their students' learning needs and goals.

Why Do Human Beings Engage? 26 Impulses That Sustain Engagement
go.nmc.org/whydohum
(Tom Vander Ark, *Getting Smart*, 12 August 2015.) The author proposes that educators can better engage students by investigating human impulses to consider the learner experience and instincts that underlie engagement and memorable experiences.

Coding as a Literacy

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

Coding refers to a set of rules that computers understand and can take the form of numerous languages, such as HTML, JavaScript, and PHP.[95] Many educators perceive coding as a way to stimulate computational thinking: the skills required to learn coding combine deep computer science knowledge with creativity and problem-solving.[96] Code.org recently projected that by 2020, there will be 1.4 million computing jobs but only 400,000 computer science students to fill them.[97] 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. Schools worldwide are developing coding programs in which students collaboratively design websites, develop educational games and apps, and design solutions to challenges by modeling and prototyping new products. Additionally, the advent of user-friendly tools including Raspberry PI, Scratch, and LegoNXT is making it easier than ever for students to begin learning to code.

Overview

As computer science remains one of the fastest growing industries across the world, schools are adjusting their curricula to train the future workforce in areas of need. In the European job market, 900,000 new ICT professionals were needed in 2015.[98] Meanwhile, in the US, hiring for positions that require programming and mobile development skills takes nearly twice as long as filling non-STEM job openings.[99] In the short term, interest in coding is largely being driven by two perceived benefits. First, programming and the development of new technologies have been linked to economic growth, leading national governments to devise strategies for integrating coding early in students' schooling.[100] Second, according to the European Commission, learning to code spurs the acquisition of 21st century skills such as creativity and computational thinking, which can be applied to many jobs.[101]

The rise of coding signals a shift from instructing students how to use computers, applications, and programs toward how they are built.[102] While current discussions about digital literacy center around learners leveraging technology to demonstrate their knowledge,[103] coding promises to move students from simply interacting with devices to controlling how those devices interact with them. As coding bolsters problem-solving and logical thinking skills, it is becoming part of national curricula, particularly in Europe. Estonia was among the first European countries to launch a pilot program in 2012 for all students from grades 1 through 12, the UK has mandated coding in primary and secondary school, and in autumn 2016, Finland will require primary students to learn it.[104] In Australia, Tasmania introduced HTML and CSS coding to the primary school curriculum in 2015. Under their statewide program, nominated representatives from each public and private primary school will receive free training from Code Club Australia.[105]

To scale this short-term trend, industry leaders are advocating for coding to be taught to youth. The Computer Science Education Coalition recently asked US lawmakers for $250 million for school districts to cultivate classrooms filled with young coders, creators, and makers. Facebook CEO Mark Zuckerberg, Amazon CEO Jeff Bezos, and other technology giants pledged $48 million dollars to this initiative, with nearly half the funding allocated to Code.org, an organization that teaches coding.[106] The nonprofit's Hour of Code has sparked a micro-learning movement, serving nearly 263 million people since its inception in 2013.[107] An annual weeklong campaign rallies schools around coding, encouraging activity sharing via the hashtag #HourofCode. More opportunities and resources are available year-round, including step-by-step guides in areas such as online game development. Partner organizations including Khan Academy, Codeacademy, and CodeHS help Code.org curate the most engaging and helpful tutorials.

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. In the US, President Obama's Computer Science for All initiative aims to equip K-12 students with computational thinking skills so they can be active participants and creators in a digital world. States will receive $4 billion in funding and school districts $100 million to expand training programs for teachers as well as access to high-quality instructional materials. In 2015, only 22% percent of students taking the AP Computer Science exam were girls, and 13% were African-American or Latino students; another goal of the initiative is to amplify outreach to minorities and underserved communities.[108] England recently revised their ICT curriculum to emphasize programming, with coding lessons developed for students as young as five years old.[109]

Advancing this short-term trend requires leaders to think deeply about how low-income communities — areas struggling with digital equity, described later in this report — can reap the benefits of coding. The nonprofit Teens Exploring Technology recently hosted a hackathon in South Los Angeles, where many students without computers could access devices to write code, build webpages, and learn key computer science and entrepreneurial skills. Professional and hobbyist programmers were on-hand to mentor students.[110] Leading organizations are also addressing persistent gender disparities in coding, as interest in computer science significantly decreases for girls between ages 13-17. Whereas in 1984, 37% of all computer science graduates were women, that percentage has dropped to 18% today.[111] Girls Who Code (GWC) aims to bridge the gap by targeting girls beginning in sixth grade to participate in coding clubs, summer immersion programs, and more.[112] While GWC currently serves 10,000 girls in 42 states, staff at schools, libraries, and community centers can also apply to launch a club.

More schools are beginning to formally include coding in their classes and extracurricular organizations. At Colfe's Preparatory School in the UK, students participating in a project-based coding club use Scratch to develop games and applications. Additionally, the trend has been incorporated in classes and cross-curricular activities, showing how various subjects are tightly interconnected with coding, such as mathematics.[113] An Australian librarian developed coding outlines for lower, middle, and upper primary schools, relying on Bee Bots and ScratchJr for the implementation. For year one and two students, equating coding with storytelling was an essential part of the learning experience as they crafted stories with narrative structure; year three and four students further honed their programming skills by investigating the complex, coding-like language of the Dewey Decimal Classification through "webquests."[114]

For Further Reading

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

Add Coding to Your Elementary Curriculum… Right Now
go.nmc.org/addingc
(Matt Harrell, *Edutopia*, 17 March 2015.) The author implores schools to make coding part of their fabric, citing children's desire to use their computers and tablets to build and create useful things. Five tips for introducing coding are recommended.

Coding Education in Schools: Crucial as English and Maths — Or is It?
go.nmc.org/orisit
(Colleen Ricci, *The Age*, 7 June 2015.) Australian parliament members are working to ensure coding is taught at all primary schools across the continent by 2020. The aim is to foster students who can design and operate the apps and devices that will fuel Australia's future economy.

Coding Education Rare in K-12 Schools but Starting to Catch On
go.nmc.org/rare
(John Keilman, *Chicago Tribune*, 2 January 2016.) A Google-commissioned survey revealed that only one out of four middle and high schools offer coding classes. Chicago-area districts are striving to improve that statistic by attaching coding lessons to non-computer science disciplines.

Coding In K12 Computer Science: It Starts From Your Imagination
go.nmc.org/startsfrom
(Jason Rukman, *eLearning Industry*, 2 July 2016.) The author laments that K-12 computer science lessons are too often derived from traditional academic methods that favor the absorption of concepts over demonstrating imagination. The inclusion of coding in digital storytelling and project-based pedagogies can help students learn programming while giving them the autonomy to explore their own creativity.

How to Teach Coding and Programming
go.nmc.org/howtoteach
(*The Guardian*, 1 September 2015.) This article encompasses examples, resources, and affordable digital tools for primary and secondary educators looking to introduce coding into their learning environments.

A New Model for Coding in Schools
go.nmc.org/anewmod
(Digital Promise, 4 August 2015.) Digital Promise points to the successful coding model of South Fayette Township School District in rural Pennsylvania. Coding is embedded in the school culture as elementary school children begin with block-based coding and high schoolers participate in AP computer science, Java and Python coding, as well as software development teams.

Students as Creators

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

A shift is taking place in schools all over the world as learners are exploring subject matter through the act of creation rather than the consumption of content. A vast array of digital tools is available to support this transformation in K-12 education; indeed, the growing accessibility of mobile technologies[115] is giving rise to an increasing level of comfort with producing media and prototypes. This may be due in part to the popularity of social media apps such as Instagram and SnapChat through which people share informal stories with photographs and short-form videos. Many educators believe that honing these kinds of creative skills in learners can lead to deeply engaging learning experiences in which students become the authorities on subjects through investigation, storytelling, and production.[116] Other aspects of this trend include game development, making, and programming which nurture learners as inventors and entrepreneurs. As students become more active producers and publishers of educational resources, it is essential that schools address the topic of fair use.

Overview

Educators can more comfortably design creative environments if they feel supported by school leaders in their capacity to experiment, improvise, and innovate. School curriculum structured around high-stakes testing often does not build in time, space, or flexibility for teachers to experiment with creative project ideas.[117] A research team recently studied 43 secondary school teachers working in the Gaziantep province of Turkey to determine key features of an empowering school culture. They found that allowing teachers to make autonomous decisions is a defining characteristic, as well as the sharing of responsibilities between principals and educators, which can establish an environment of teamwork and trust.[118] When educators are actively experimenting in the classroom, students in turn are more likely to confidently take creative risks themselves. It is also important that educators provide opportunities for students to take ownership of their learning and depart from teacher-defined outcomes without being penalized.[119]

To help students adopt the habit of setting personal learning goals, some educators are working with their classes to co-develop curriculum. A recent study of third-grade students at an elementary school in Arkansas found that student-led lesson planning was a successful tool for promoting creativity and engagement, while bolstering student understanding of complex concepts.[120] The trend of empowering learners as creators is also driving a shift in how subject mastery is assessed toward more participatory methods in which students help define the competencies, goals, and skills they are working to achieve. Digital tools, such as mobile apps with built-in analytics and adaptive learning platforms, can provide more opportunities for monitoring and tracking various steps within the context of hands-on learning activities so that the learning environment becomes more supportive of the creative process.[121]

Free or affordable platforms including Socrative, Kahoot, Nearpod, and Google Forms can capture and store evidence of learning progress, while allowing them to provide constructive feedback that can refine students' ideas, products, and processes.[122] Collaboration, communication, information literacy, and global awareness are some examples of 21st century skills that can be defined and built into assessment; students can reflect upon how specific skills and tools enable them to reach their goals.[123] The National Science Foundation promotes a three-dimensional view of learning that includes both summative and ongoing formative assessment and encourages a collaborative approach between students and teachers in designing, enacting, and refining assessment. Informal assessment can be embedded in daily classroom practice, with the goal of guiding students around self-reflection and self-evaluation so they can make the appropriate revisions to their work products.[124]

Implications for Policy, Leadership, or Practice

While access to internet-enabled technologies makes it easy for people to create media and products and share them with the world, there can be heavy legal repercussions such as lawsuits associated with fair use. Educating school staff and students on the topic is vital.[125] More than 40 countries' copyright laws have fair use or fair dealing provisions; however, only eight have a flexible fair use limitation on copyright infringement and the rest rely on fair dealing, where an action is fair only if it is directed toward a predetermined list of purposes.[126] Several advocacy groups and initiatives aim to inform policy changes that accommodate freedom of speech and expression while protecting the work of students and educators. The Association of Research Libraries underscored the importance of the right to fair use by launching Fair Use Week — known as #FairUseWeek2016 on social media — to publicize fair use and the related opportunities and issues, as well as to promote cultural and scientific progress.[127]

Schools can partner with other organizations to help them maximize the creative opportunities technology allows. The Learning About Multimedia Project in New York City provides free access to emerging technologies as well as workshops at local schools in order to prepare youth to comprehend, critique, and create media.[128] School leaders are also working to embed creativity and student voice into their missions and school cultures. Big Picture Learning has developed a network of more than 60 schools across the US that offer self-directed learning programs in which each student creates their own curriculum, tailored to suit their personal interests; students work with advisors, industry professionals, parents, and peers to learn how to manage their own yearlong projects such as designing a clothing line or producing a film.[129]

Whether in classroom settings or elsewhere, students have access to a wealth of information, but as creators they must learn to properly evaluate and take advantage of credible resources to support their projects and goals. Students at South Miami Middle Community School, for example, tracked climate change by downloading satellite image data from the NASA NEO website and creating montages to share their findings.[130] The act of creating videos and other forms of media, including games, can also clarify complex subjects. In "Minecraft," a popular digital game, students can create visual representations and simulations of concepts they are studying while learning problem-solving skills.[131] Creative tasks empower students as they gain confidence in applying knowledge toward real scenarios. The Evangelical School Berlin Centre teaches students the importance of motivating themselves by allowing them to choose subjects they are interested in studying and to determine which platforms best showcase their newly acquired skills, such as coding a computer game.[132]

For Further Reading

The following resources are recommended for those who wish to learn more about students as creators:

Encourage Your Students to Plan the Unit of Inquiry
go.nmc.org/enco
(IB Educator, *Sharing PYP Blog*, 24 May 2016.) A group of year eight students at Selwyn House School in New Zealand developed curriculum around a relevant real-world problem of their choosing. Their planning led to transdisciplinary activities involving research, critical thinking, empathy, reflection, and communication as they explored what it might be like to spend a day in a refugee camp.

Helping Students Find Identity Through Student Created Video
go.nmc.org/identit
(Matt Miller, *TechSmith*, 3 September 2015.) A high school Spanish teacher found that when his students created videos they explored aspects of the language related to their personal passions and interests. Students engaged in a full production process including storyboarding, designing, recording, and editing video using Camtasia Studio, as well as research and content licensing, proofing, and publishing their final products.

How a Nonprofit is Using Video Games to Strengthen Students' Writing Skills
go.nmc.org/histri
(Amy Bishop, *Houston Public Media*, 18 May 2016.) Game-based learning company Histrionix recently partnered with the national nonprofit Writers in the Schools to allow students to turn their creative writing into video games published online for others to play.

'Student Agency' Is Not Something You Give or Take
go.nmc.org/studagen
(Andrew Rikard, *EdSurge*, 16 October 2015.) This essay emphasizes the importance of student agency in a world that needs makers and creators. Educators can impart relevant skills in students by collaborating with them, treating them as equals, and embracing failures.

Testing Time at Schools: Is There a Better Way?
go.nmc.org/testtime
(Kelly Wallace, *CNN*, 4 April 2016.) Eight US states now allow parents to opt out of standardized testing for their children. The author delves into how assessment software could provide accountability on a national scale while measuring student progress by capturing creative projects on a granular level.

The Whole Truth about Copyright
go.nmc.org/wholetruth
(Mary Beth Quirk, *Consumerist*, 26 February 2016.) Misinformation and confusion persists about what "fair use" entails. This article describes how a number of leaders in the field are working to educate youth about their rights so they will not be fearful or deterred from using and creating digital media.

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 was captured in the online work site used by the expert panel and archived at k12.wiki.nmc.org/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 NMC 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 they were examined through three meta-expressions: their implications for policy, leadership, and practice.

Policy. While all of the identified challenges had policy implications, two specific challenges are driving policy decisions at many schools at the moment. The easiest one to address is creating policies that spur the development of more authentic learning experiences. A framework drafted by Ontario Ministry of Education aims to catalyze more community-connected, experiential learning. Key to this government initiative is the philosophy that community partnerships can help students become global citizens who better understand how their skills can contribute to bolstering the economy.[133]

A more difficult area is creating policies that transition teachers into the 21st century classroom role of guide and coach rather than lecturer. This challenge is exacerbated by the rapidly evolving digital landscape in which educators are increasingly expected to be technologically savvy in order to instill digital literacy skills within their students. Governments are tasked with understanding the kinds of support that teachers need to adopt student-centered pedagogies. "Digital Strategies for Schools 2015-2020," a policy document from Ireland's Department of Education and Skills contains professional development strategies to aid in-service teachers as they facilitate more active learning.[134]

Because not all challenges are of the same scope, the discussions here are sorted into three categories defined by the nature of the challenge.

Leadership. Again, while all the identified challenges have leadership implications that are discussed in the following pages, two pose roadblocks to employing effective vision and leadership. The expert panel perceives that advancing digital equity is a difficult task that leaders are just beginning to address effectively. Despite the ever-increasing amount of learning materials and resources made available online, not all learners have sufficient access to high-speed broadband internet at home to complete assignments. This notion has incited an even greater rift between the *have's* and *have not's*, leaving K-12 stakeholders especially concerned about the Homework Gap. CoSN's new *Digital Equity Action Toolkit* is aimed at education leaders in high-poverty districts, equipping them with strategies and information to cultivate greater technology use in out-of-school learning experiences.[135]

The most wicked leadership challenge is the achievement gap that persists, in which low-income students and other underserved learner populations struggle to stay in school and graduate with skills that translate to gainful employment. Schools need ongoing leadership around devising solutions for disadvantaged students. In New Zealand, teachers help each other identify and address at-risk learners through the Ministry of Education's Investing in Educational Success initiative, and the complementary Teacher-Led Innovation Fund supports the co-design of activities that improve student success.[136]

Practice. Each of the six challenges identified by the expert panel presents numerous impediments for advancing teaching and learning in K-12 education, but two in particular are posing unique obstacles. Categorized by the expert panel as difficult, the act of scaling teaching innovations requires school cultures that encourage education professionals to experiment with and collaborate on new approaches. At Denver Public School, the Imaginarium is an innovation lab where educators, students, and administrators employ design-thinking principles to move new models from conception to implementation, with an emphasis on scaling big ideas.[137]

Catering to each student by providing customized learning activities and support requires careful implementation and has been identified as a wicked challenge. There is not yet consensus around what personalized learning means, and definitions are often nebulous. However, a growing host of technologies are enabling more individualized attention. Adaptive platforms, for example, are viewed as a catalyst for personalizing learning. Schools in Singapore are piloting an adaptive learning platform for mathematics with which teachers are privy to analytics on student progress and can adjust their instruction to better accommodate student needs. The hope is that students will also have more autonomy in the kinds of materials they use during the learning process, leading to increased engagement and accountability.[138]

The following pages provide a discussion of each of the challenges highlighted by this year's expert panel that 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, those that bring students in touch with real-world problems and work situations, are still not pervasive in schools. 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; these approaches include vocational training, apprenticeships, and certain scientific inquiries.[139] Advocates of authentic learning underscore the importance of metacognitive reflection and self-awareness as cornerstones.[140] 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 of school.[141]

Overview

Authentic learning prepares students by equipping them with the skills needed to be successful in higher education and the workforce.[142] The trend toward deeper learning, featured earlier in this report, runs parallel to this challenge because they both highlight the movement toward incorporating experiential and hands-on learning in schools. This challenge is perceived as solvable because its dimensions and solutions are well understood. A recent post by *Teach Thought* notes that there are five major obstacles to incorporating real-world learning in schools: curriculum and content standards being too rigid; testing and accountability driving pedagogical decisions; schedules being too regimented and silos too restricting; educator practice requiring more risk-taking; and policy fostering a culture of achievement instead of teaching and learning.[143] Similarly, a Digital Promise survey found that one of the biggest challenges in K-12 education was creating real-world learning opportunities. Fortunately, supportive administrations are paving the way to incorporating more authentic approaches such as challenge-based learning.[144]

Whether the goal is to improve retention, build upon their natural passions and interests, or expose them to work situations, authentic learning strategies cultivate within students a greater understanding of their abilities and purpose beyond the classroom. One commonly seen approach to creating this connection is through the development of partnerships with local businesses, organizations, and public entities in the community. The Kansas City Neighborhood Academy, for example, partners with local universities on curriculum projects such as crime scene investigation; businesses such as SunTrust on a miniature youth bank, and local community organizations such as the East Lake Golf Cub on internships and special events. These collaborations offer students the opportunity to develop learning experiences tied directly to real-world careers.[145]

The apprenticeship, a historical model that has faded over time, is experiencing a resurgence as more schools see the value in creating vocational programming for students. Apprenticeships have many benefits as they help students earn a salary, build skills employers want, increase earning potential, and learn at their own pace.[146] Virtual Enterprises International (VEI) is a New York-based workforce development program modeled off of effective apprenticeship initiatives in Austria and Germany. Students at VEI-hosted schools apply what they learn in class to a real-world business setting. They learn the major components of running a company such as paying taxes, managing payroll, and working with bank accounts.[147] At VEI 2016 Youth Business Summit, 300 students from eight countries reviewed a business case study about Sony's PlayStation 4, developed a business strategy, and pitched their plans to the head of marketing.[148]

Implications for Policy, Leadership, or Practice

While educators are embracing the concept of authentic learning, there is a need for more concrete policies that stimulate the interest of schools and help guide them throughout the process. The Canadian government has created a policy framework draft for schools to generate more community-connected, experiential learning. The Ontario Ministry of Education believes that dynamic community partnerships should serve as a foundational experience for students to cultivate citizenship as well as the knowledge and skills needed for students to succeed personally and economically.[149] Similarly, in England, proposed legislation by the Department for Education would provide students with more opportunities for apprenticeships by requiring schools to collaborate with training providers and technical colleges.[150]

In order to facilitate real-world learning, school leaders must be aware of what effective support models, training strategies, and resources already exist. The recent OECD and European Commission publication *Entrepreneurial School* describes the elements of entrepreneurial education in schools with particular attention to learning environments, the changing roles of educators, and how schools collaborate with surrounding organizations. They explain that schools can benefit from community partnerships because they provide additional resources for students such as professional expertise and access to costly engineering tools.[151] In Australia, the Sydney Catholic Schools has created an authentic learning toolbox that enables teachers to share ideas, practices, resources, and experiences; the website includes links to real-world assessment information, Australian Professional Standards, a Google+ learning community, and more.[152]

Citizen science, which involves a partnership between volunteers, amateurs, and trained scientists, is viewed as one way to offer students authentic learning experiences in community awareness, scientific inquiry, critical thinking, and problem-solving.[153] Through the Vermont STEM Leadership Institute, a collaboration between the University of Vermont and five school districts, teachers are learning how to integrate citizen science into their curricula. One participating teacher noted that students are more engaged and enthusiastic when performing authentic scientific investigations.[154] As part of the Natural History Museum of Los Angeles County's urban research study SuperProject!, three third-grade classes from Billy Mitchell Elementary School conduct observations in their school garden, giving them a greater appreciation for nature and the world around them. Upon observing the presence of a Southern alligator lizard, for example, the students uploaded a new record to iNaturalist's website, contributing to a larger scientific study.[155]

For Further Reading

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

HIVE Learning Network
go.nmc.org/hivelearn
(HIVE Learning Network, accessed 25 July 2016.) The HIVE Learning Network joins communities around the world to enhance digital skills of students through connected learning. Organizations such as libraries, museums, schools, and nonprofits help students learn these 21st century skills through hands-on making and exploration with peers and mentors.

How Effective Are 'Career Academies'?
go.nmc.org/caracad
(Melinda D. Anderson, *The Atlantic*, 19 April 2016.) A new career academy focusing on firefighting will open at Pine Forest High School in Florida, joining a roster of other academies that include a partnership between West Florida High School and the regional utility company Gulf Power.

Preparing Students for Life and Work
go.nmc.org/preps
(Margaret Hilton, *Issues in Science and Technology*, Summer 2015.) Schools must develop 21st century skills in students that involve teamwork, problem-solving, and self-management. For this to happen effectively, federal and state policy needs to evolve to address curriculum, instruction, assessment, and professional development requirements.

Real World Learning Using Project-Based Learning
go.nmc.org/gvas
(Global Village Academies, accessed 25 July 2016.) Global Village Middle Schools are working with New Tech Network (NTN) on project-based learning programs to engage middle school students in real-world learning activities. NTN offers a standards-based project library to help students connect with their local communities.

Virginia Heading for Dramatic High School Overhaul
go.nmc.org/virginia
(Travis Fain, *eSchool News*, 6 April 2016.) Virginia high schools are planning new opportunities for the 2018 freshman class, including credit for internships and apprenticeships, and allowing industry certifications and state licenses to take the place of Standards of Learning tests. Students can graduate from high school with a certification to work in the industry of their choice.

Rethinking the Roles of Teachers

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

Teachers are increasingly expected to be adept at a variety of technology-based and other approaches for content delivery, learner support, and assessment.[156] In the technology-enabled classroom, teachers' primary responsibilities are shifting from providing expert-level knowledge to constructing learning environments that help students gain 21st century skills including creative inquiry and digital literacy.[157] Educators are now acting as guides and mentors, modeling responsible global citizenship and motivating students to adopt lifelong learning habits by providing opportunities for students to direct their own learning trajectories.[158] These evolving expectations are changing the ways teachers engage in their own continuing professional development, much of which involves social media, collaboration with other educators both inside and outside their schools, and online tools and resources. Pre-service teacher training programs are also challenged to equip educators with digital competencies amid other professional requirements to ensure classroom readiness.

Overview

As detailed in the Deeper Learning Approaches and Collaborative Learning topics of this report, schools are increasingly incorporating activities that foster active learning and promote problem-solving skills. Teachers' duties are changing to embrace a role of curating and facilitating learning experiences and encouraging student exploration to discover passions.[159] The rise of blended and online learning is contributing to this shift;[160] with a wealth of content available online, teachers are no longer expected to serve as the sole authoritative source of information in the classroom. A report by Ecorys has identified improving digital literacy as critical to the health of the UK's economy, and advocates that schools design learning environments that use technology to promote creative inquiry and collaboration.[161] While traditional responsibilities remain within teachers' purview, including assessment, discipline, and classroom management, educators are now expected to incorporate technology into their pedagogical strategies to meet the needs of 21st century learners.[162]

A survey of US educators by Samsung and GfK revealed that 81% view technology as an important gateway to provide hands-on experiences for students, yet one in three respondents felt that their schools do not provide adequate support to help them integrate technology in the classroom.[163] Schools are challenged to create agile environments that support the development of professional learning networks where educators can seek guidance and inspiration from peers around the globe as they rethink their pedagogies and curricula.[164] Additionally, teacher education programs, lacking curriculum flexibility amid state-mandated requirements, often gloss over digital learning strategies and the use of technology to enable individualized learning pathways in the classroom. Hiring practices that do not reflect technology's central role in education are compounding this challenge: many school administrators continue to prioritize candidates' educational backgrounds over their technical knowledge.[165]

Professional development and teacher training play a vital role in schools providing more student-centered learning and creative opportunities. Teachers are now tasked with changing their leadership style from directive to consultative and involving students in planning, implementation, and assessment.[166] At Harmony Public Schools, a network of STEM schools in Texas and Washington, DC, teachers act as facilitators of collaborative, interdisciplinary projects, and they rely on each other to share expertise and provide support.[167] Continuing professional development will also be instrumental in helping teachers fulfill students' emerging needs as technology-enabled education practices continue to evolve.[168] A recent doctoral study of Australian school classrooms across two years found that a group of teachers characterized as "high-end early tech adopters" integrated technology in similar, successful ways, including the use of technology to allow students to reflect, create and produce, demonstrate and share, and take ownership of their learning.[169]

Implications for Policy, Leadership, or Practice

Government action will be key to helping educators keep pace with 21st century learners. An OECD survey revealed that Australian teachers on average partake in just nine days of continuing professional development each year.[170] A government initiative in partnership with two universities is working to improve access by offering free, high-quality continuing professional development courses online. Queensland's Department of Education and Training will sponsor "Developing Our Teachers," an opportunity for educators to increase their digital competencies and discover best practices for teaching STEM subjects.[171] Ireland's Department of Education and Skills' "Digital Strategies for Schools 2015-2020" document outlines policies for supporting professional development to help teachers enable active learning through constructive usage of technology in the classroom, as well as promoting the use of ICT to form communities of practice. The strategies acknowledge the continuum of skill levels possessed by in-service teachers and recommend a variety of approaches to meet educator needs.[172]

Education-focused organizations and agencies are joining forces to design solutions that help teachers manage their evolving roles. European Schoolnet, a network of 31 European Ministries of Education, has created the Teacher Academy,[173] a resource offering in-person training opportunities, free online courses, and teaching materials in multiple languages. The site is intended to help educators address challenges related to rapid technological changes and to increase accessibility of professional training. Free online courses in 2016 include project-based learning, supporting diverse learners, and 21st century competencies.[174] Educators can also benefit from innovative learning models such as the Technological Pedagogical and Content Knowledge (TPACK) framework, which describes the types of knowledge teachers need to effectively integrate technology into curricula. The National Technology Leadership Coalition, a US-based consortium that fosters cross-disciplinary collaboration around education technology and educator preparation, has created the Practitioner's Guide to TPACK, a site with video case studies on technology implementation strategies to increase learning outcomes.[175]

Efforts are underway to help educators transform their teaching practices, enabled by technology. Calcasieu Parish Public Schools in Louisiana offers a district technology training center for teachers to receive hands-on instruction, on-campus technology facilitators for just-in-time assistance, and a host of webinars for flexible learning opportunities. Educators' professional development hours are tracked as "tech points," which can be redeemed for access to additional technology in their classrooms.[176] Educators are also exploring alternative instructional and assessment models. A South Korean government initiative introduced a test-free semester program in 42 middle schools to enable students to explore interests in a supportive environment. To measure students' progress without exams or scores, teachers increased their attention to individual students and engaged in continuous evaluation throughout the program.[177]

For Further Reading

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

Horizontal Professional Development
go.nmc.org/teach21
(Linda Hippert, *Getting Smart*, 11 August 2015.) Teachers in the greater Pittsburgh area are reinventing professional development through cross-district collaborations in which exemplars share expertise and assist others in implementing new technology initiatives.

How Peer Video Coaching is Completely Changing How Our Teachers Teach
go.nmc.org/videopd
(Diane Lauer, *eSchool News*, 2 February 2016.) St. Vrain Valley School District has implemented an online video coaching platform for teachers' professional development, promoting agile recalibration of teaching methods.

How to Manage a Digital Classroom
go.nmc.org/digiteach
(Anita Townsend, *TEACH Magazine*, accessed 5 August 2016.) This article offers practical tips and pedagogical strategies to help teachers plan and supervise students' use of technology in the classroom.

Reimagining Classrooms: Teachers as Learners and Students as Leaders
go.nmc.org/techkids
(Kayla Delzer, TEDxFargo, 13 October 2015.) In a North Dakota second-grade classroom, students teach each other how to use education apps. This model promotes student ownership of individual learning trajectories.

UNESCO Launches Teacher Professional Development Project
go.nmc.org/unescotrain
(UNESCO, 28 October 2015.) In collaboration with the Queen Rania Teacher Academy, UNESCO's Blended Approach to Teacher Training initiative will provide a mix of online resources and face-to-face instruction to support Jordan's STEM subject teachers.

What Matters Now: A New Compact for Teaching and Learning
go.nmc.org/whatmat
(National Commission on Teaching & America's Future (NCTAF), 2016.) This NCTAF report issues a call-to-action for education leaders to work toward a future where even the most low-income students benefits from effective teaching practices.

Advancing Digital Equity

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

Digital equity refers to uneven access to high-speed broadband,[178] a rampant social justice issue that is not just impacting developing nations. Pew Research reports that five million households in the US with school-aged children are not privy to high-speed service.[179] While more schools are benefiting from improved internet connectivity,[180] the growing pervasiveness of blended learning approaches is illuminating new gaps between those with and without high-speed broadband; especially in countries that emphasize homework, students are increasingly expected to engage in learning activities outside of the classroom. For students from economically disadvantaged households, the availability of broadband and sufficient computing devices is not a given. This facet of digital equity is also referred to as the Homework Gap,[181] and solving this challenge will take concerted efforts between policymakers and school leaders. In the US, President Obama recently announced the ConnectALL initiative, which promises high-speed broadband and technology access for every American. Further, internet and technology providers such as Google are enabling greater access in low-income areas by providing entire cities with gigabit fiber connectivity.[182]

Overview

While advancements in technology have made it easier than ever to access high-quality learning resources and communicate with peers, connectivity challenges persist globally. Growth of high-speed broadband is not evenly distributed. Alliance for Affordable Internet reveals that the world's least developed nations, such as Guinea-Bissau, Madagascar, and Cambodia, will not have universal and affordable web access until 2042.[183] The US's E-Rate program, directed by the Federal Communications Commission (FCC) and administered by the Universal Service Administrative Company, is a seminal initiative launched in 1997 to help schools and libraries obtain affordable high-speed internet.[184] The program was recently modernized with more funding allocated to support better digital learning infrastructure in schools and districts; State Educational Technology Directors Association (SETDA) and Common Sense Kids Action have developed free resources to aid state and local policymakers in securing broadband connectivity in their jurisdictions.[185]

As K-12 learning activities more frequently take place online, particularly in flipped classroom and other blended learning models,[186] there are greater expectations around students' ability to engage in projects and assignments outside of school, and particularly at home. This notion is only exacerbating the age-old premise of the *haves* and *have-nots*. According to a 2014 report by the US Census Bureau, households with annual income of $25,000 are about 50% less likely to have broadband access than those bringing in $150,000 or more.[187] Education Superhighway reports that 21 million students and 23% of school districts still do not satisfy minimal bandwidth goals for digital learning. To meet the high-speed connectivity demand predicted for 2018, school districts will need to increase bandwidth at least threefold.[188] Organizations such as Internet2, founded by several leading universities, are working to solve this challenge, providing collaborative opportunities for US research and education leaders to devise innovative technology solutions.[189]

In developing nations, obtaining high-speed internet access is secondary to addressing more drastic challenges, such as a lack of electricity.[190] While the Kenyan government aims to supply Kenyan primary schools with laptops in the coming years, 20% of those schools are still not on the electrical grid and do not have the most basic necessities required to leverage these devices; 70% of people living in sub-Saharan Africa have no access to electricity.[191] In many Middle Eastern countries such as Afghanistan, digital inequity abounds as the United Nations Science and Technology Group for Development reports that ICT strategies are "often developed and publicized mainly to attract external investment to construct new infrastructures or to market hardware and software without giving sufficient attention to local concerns and requirements."[192] Without high-speed internet access, successful scaling of emerging technologies in education is moot.

Implications for Policy, Leadership, or Practice

The US Department of Education updated its National Education Technology Plan in 2015 to better address digital equity concerns. Among the recommendations was the redesigning of teacher training programs to support incoming teachers with creative ways to use technology to bolster their levels of proficiency while ensuring fair access to the internet regardless of students' socioeconomic backgrounds. The latter proposal is contingent upon the nation updating its overarching technology infrastructure to meet future connectivity demand.[193] ConnectHome, another Obama administration initiative, aims to provide high-speed internet access to more than 275,000 low-income households at an affordable price. Pilot programs are taking place in urban hubs including New York, Boston, and Seattle.[194] Further, the related ConnectED initiative is specifically focused on advancing digital equity in K-12, calling for states, schools, and districts to support a vision of sufficient internet connectivity for all students and teachers.[195]

While governments continue to develop digital equity strategies, internet providers are also stepping up. Comcast's Internet Essentials program brings affordable broadband to low-income American families at under $10 monthly; nearly 1.5 million children from 350,000 families have benefited.[196] Despite progress, only 2.9 billion people of the 7.2 billion world population are connected to the internet. Facebook is leading work to increase global access to online learning resources.[197] CEO Mark Zuckerberg traveled to rural India to investigate leveraging existing infrastructure to provide access to the web and educational materials with a mere 2G connection. Facebook's not-for-profit arm, Internet.org, launched an app in Zambia and Ghana that can be embedded in most basic mobile phones, making resources including Wikipedia, Google Search, BBC News, and the Mobile Alliance for Maternal Action available to all users.[198] Additionally, advocacy organizations such as CoSN aim to bridge the Homework Gap. Their *Digital Equity Action Toolkit* provides education leaders in high-poverty districts with timely information to expand technology use in out-of-school learning.[199]

Barriers to advancing digital equity are exacerbated as schools adopt flipped classroom approaches that rely on high-speed internet connectivity at home. In practice, resourceful schools are overcoming these obstacles by providing students with greater flexibility and alternative places to do their homework. Warren Township High School in Illinois now gives students two days to complete flipped classroom assignments, extended their library hours, and remodeled the web-connected space to accommodate more students.[200] New York's Watkins Glen Central School District recognized that high-speed internet access dropped off just three miles outside of town, making it difficult for every student to engage in learning activities at home. To solve this challenge, they equipped their fleet of 18 school buses with industrial integrated-services routers to enable learners to do assignments on the way to and from school.[201]

For Further Reading

The following resources are recommended for those who wish to learn more about advancing digital equity:

The FCC Wants to Help Everyone Afford High-Speed Internet
go.nmc.org/fcc
(Lance Whitney and Marguerite Reardon, *CNET*, 8 March 2016.) The FCC is expanding their $1.5 billion program, Lifeline, in an effort to provide broadband internet to low-income families at $9.25 per month.

How to Close the 'Homework Gap' in the Digital Divide That's Holding Back Our Kids
go.nmc.org/homegap
(Eva M. Clayton, *The Root*, 28 June 2016.) This article describes how free mobile data programs are enabling students without internet connectivity at home to complete assignments via broadband.

Mapping the Digital Divide
go.nmc.org/mapp
(Council of Economic Advisers, July 2015.) The Obama administration issued a brief documenting the digital divide, linking the latest Census Bureau's American Community Survey with the National Broadband Map to examine internet usage in a granular manner.

Rich People Have Access To High-Speed Internet; Many Poor People Don't
go.nmc.org/richppl
(Allan Holmes et al., *The Huffington Post*, 12 May 2016.) Some K-12 leaders believe that internet access is a civil rights issue, citing the lack of high-speed broadband as a barrier for people to pursue lucrative careers.

Teachers Fear a 'Digital Divide', as Parents Concerned about BYOD Costs
go.nmc.org/smh
(Esther Han, *The Sydney Morning Herald*, 10 January 2016.) In New South Wales, Australia, parents are struggling with a government mandate to purchase $1,200 devices for their children. The BYOD model encourages personal technology use for learning but sets unfair expectations for low-income households.

When Students Can't Go Online
go.nmc.org/whenst
(Terrance F. Ross, *The Atlantic*, 13 March 2015.) This article provides an overview of school and library internet connectivity, emphasizing that high-speed web access is a necessity for student success.

Scaling Teaching Innovations

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

Schools are not yet adept at moving teaching innovations into mainstream practice. Innovation springs from the freedom to try out and implement new ideas, yet schools generally allow for top-down changes that unfold in prescribed ways. Success in teaching is closely tied to test results, and teachers are not frequently rewarded for innovative approaches and improvements in teaching and learning, much less allowed to scale and replicate these breakthroughs. As a result, many educators become frustrated by the rigid confines of a school that is in desperate need of transformation. Scaling pedagogical innovation requires adequate funding, capable leadership, strong evaluation practices, and the removal of restrictive policies — a tall order for the majority of K-12 public schools, which are receiving fewer resources.[202] The reality is that many teachers are not prepared to lead innovative, effective practices, and there is a kaleidoscope of systemic factors that must be addressed to resolve this complex issue.[203]

Overview

Scaling teaching innovations is an especially difficult challenge because variables such as teachers' content preparation, students' self-efficacy, and prior academic achievement vary across different contexts and significantly impact the effectiveness of educational interventions.[204] Additionally, schools and districts often run into obstacles when implementing new pedagogies across the board. Online learning, for example, has been a driver of many teaching innovations, but teachers frequently lack the time required to experiment and the institutional support needed to expand upon grassroots efforts.[205] Indeed, financial issues are often cited as the main challenge to growing teaching innovations. The final report from the US reading initiative, Success for All, noted that resource constraints prevented the full implementation of program features, and a cost analysis found that program schools spent $227 worth of resources for each student per year more than in control group schools.[206]

While evidence indicates that the broad implementation of pedagogies, such as project-based learning where students learn core subjects through business and community projects, improve student engagement and outcomes, they are slow to gain traction.[207] Education leaders believe that there are several obstacles in deploying PBL approaches before it becomes more mainstream in school; approaches are currently too bespoke in nature, there are not enough opportunities to share successes, and there is a lack of professional development opportunities.[208] More often, charter schools have the agility to implement successful new pedagogical approaches, such as the Uncommon Schools which use the Lemov Taxonomy of Effective Practices philosophy,[209] but charter school leadership is so focused on managing their own small network that they rarely work with school districts which oversee the largest number of schools.[210] Further, the American Enterprise Institute report *Scaling Up* noted that the major impediments to growing high-quality charter networks are related to regulatory, financial, and human-capital issues.[211]

While this challenge is perceived as difficult in nature, success is happening in pockets across the developing world. In the Brookings Institute report *Millions Learning*, which includes in-depth case studies from Brazil, Uganda, and India, they explain that successful amplification happens when pilots are properly incubated and then spread to reach more youth. Margins vary, but can include governments providing school officials freedom to experiment or community movements intended to provide greater access to learners whose educational options are limited. Optimal conditions in which innovation can proliferate include planning growth from the outset, understanding the operational realities of delivery, financing in a flexible and stable manner, and creating an enabling policy environment.[212]

Implications for Policy, Leadership, or Practice

Policies that support innovation in teaching, although rare, are paving the way for states and districts to scale novel models of instruction. Since 2010, the US Department of Education's Investing in Innovation (i3) program has been providing grants to educators for scaling innovation aimed at improving student outcomes.[213] The New Teacher Center is a two-time i3 Scale-Up grantee that works with policymakers in many US states to shape legislation, rules, regulations, and program standards for improving student success.

At the state level, Arkansas has created the Districts and Schools Innovation program where state rules and regulations are relaxed for approved schools to develop transformational teaching models. One of their initiatives is convening an Innovation Summit to share innovative learning models around the state and beyond.[214] On a global level, many initiatives cite the United Nations Sustainable Development Goal to ensure inclusive and equitable quality education as a main driver for the development of educational transformation policies.[215] By 2030, the UN aims to ensure that all children can complete free, equitable, and quality education with relevant and effective outcomes.[216]

Recognizing and assisting schools that have successfully scaled teaching innovations is a crucial part of addressing this challenge. LEAP Innovations is a Chicago-based nonprofit working to help educators discover, pilot, and scale innovative teaching solutions. Under LEAP Innovations' leadership, the collaboration created three key initiatives aimed at developing a hub for practitioners and stakeholders, a research network for pilot programs, and professional development opportunities and funding to scale personalized learning approaches in schools.[217] Similarly, Qatar Foundation's World Innovation Summit for Education (WISE) is an international opportunity for creative thinking, debate, and purposeful action for new approaches in education. Through their annual WISE summit, research, and programs, they are building the future of education through collaboration.[218] Their recent paper "Creative Public Leadership" is aimed at helping school leaders create the proper conditions to foster system-wide innovation.[219]

Some school districts are prioritizing educational transformation by creating new departments or partnering with organizations to help stimulate and support grassroots innovation on campuses. The Imaginarium, for example, is Denver Public School's official innovation lab. Using design thinking backed by research, they work directly with students, educators, and administrators to take initiatives from idea to implementation stage with an eye toward scaling.[220] In Canada, the Toronto District School Board has partnered with the MaRS Solutions Lab, an organization that helps scale innovative solutions to the world's most pressing problems, to promote experiential and self-directed learning. At a teachers-in-residence summer institute, the partnership developed an initiative to embed entrepreneurial thinking and student entrepreneurship into the K-12 curriculum.[221] The "MaRS Entrepreneurial Thinking Toolkit for K-12 Educators" was an important development that will aid the school district and be shared with other school boards and innovation centers.[222]

For Further Reading

The following resources are recommended for those who wish to learn more about scaling teaching innovations:

Bill & Melinda Gates Foundation K-12 Education Initiative
go.nmc.org/bmgfk12
(K12 Education Gates Foundation, accessed 15 August 2016.) A goal of the Bill & Melinda Gates Foundation's K-12 strategy is to build greater bonds between public school teachers and students. The team includes a strategy leader to engage teachers to improve practice and encourage innovation at scale.

From Print to Pixel: The Role of Video Games, Animations, and Simulations within K-12 Education (PDF)
go.nmc.org/speak
(Project Tomorrow, accessed 15 August 2016.) The Speak Up research project annually polls K-12 stakeholders about the role of technology for teaching and learning to provide data to help scale high-impact innovations.

Scaling Up Educational Interventions in Nigeria
go.nmc.org/techmap
(Nigerian Education Innovation Summit, 19 July 2016.) This communiqué posits that a systematic approach to challenges is necessary to increase quality education in Nigeria and puts forth a call to action to identify best practices for engaging policymakers and to scale up evidence-based education interventions.

Teacher-Led Innovation Celebrated at Summit in Minneapolis
go.nmc.org/minnpost
(Erin Hinrichs, *MINNPOST*, 14 June 2016.) In a Shark Tank-style event, 20 teachers and administrators presented new approaches to learning in the classroom.

Teacher Teams and School Processes in Scaling-Up a Content Literacy Innovation in High Schools
go.nmc.org/teateams
(Denis Newman et al, *Empirical Education*, December 2015.) Research analysis of Reading Apprenticeship, a five-year high school content literacy intervention program, found that although there were high levels of buy-in during the first year, competing initiatives and decreased enthusiasm were obstacles to success.

Unlocking the Future of Education in Columbia
go.nmc.org/idrc
(International Development Research Centre, accessed 15 August 2016.) Information and communication technologies have become more affordable in Latin America, making it possible to transform teaching and learning. A project led by Universidad EAFIT in Columbia will identify best practices and test educational innovations.

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 between student groups, especially as defined by socioeconomic status, race, ethnicity, or gender.[223] Environmental factors such as peer pressure, student tracking, negative stereotyping, and test bias are exacerbating this challenge. Schools use various success standards to define learning expectations, including grades, standardized test scores, and completion rates, leading to comparison of student performance at the individual and group level. Adaptive and personalized learning technologies are beginning to play a more integral role in identifying lower-performing students and student populations, helping educators and leaders understand contributing factors, and enabling and scaling targeted intervention methods and engagement strategies that help close the gap. Global concerted action will be necessary, however, to address ongoing obstacles to education for children in countries experiencing civil unrest, as well as cultural barriers depriving females' access to school.[224]

Overview

An abundance of research supports the relationship between socioeconomic status (SES) and student achievement.[225] This can be understood by examining disparities in opportunity and resources. Children of poverty face obstacles that impact their ability to perform in school, such as a lack of access to quality health care leading to poor attendance.[226] Further, education funding initiatives designed to raise all student outcomes across the board are not tailored to address the needs of specific underperforming student populations.[227] Progressive systems that provide more funding to higher-need schools can help correct this imbalance. A 20-year longitudinal study by the US Educational Testing Service found that investment in lower student-teacher ratios and higher teacher wages resulted in schools with smaller achievement gaps and better educational outcomes for low-SES students.[228]

Ongoing conflict in countries in the Middle East and North Africa has resulted in a lack of access to education for nearly 4.5 million children. In the Arab world, girls do not have equal opportunity to attend school, particularly in Djibouti, Sudan, and Yemen.[229] The US Agency for International Development (USAID) reports that 62 million young girls worldwide are not attending classes.[230] Several USAID strategies are working to combat this challenge, including the Let Girls Learn initiative, which invests in private-public partnerships and programs to help girls access school and build leadership skills.[231] Other inequities based on gender with roots in K-12 education include the underrepresentation of women in STEM fields. An Israeli study found that elementary school teachers' unconscious biases in favor of males resulted in giving lower marks to females, where gender-blind assessments showed increased scores for girls. The study found that this stereotyping impacted the two groups' future enrollment in advanced math and science courses in secondary education.[232]

East Asian economies, including Shanghai, Singapore, Hong Kong, and South Korea, have scored in the top ten globally in terms of student achievement as measured by the OECD's Programme for International Student Assessment (PISA); yet they also have lower proportions of underperforming students, indicating that improving learning for low performers does not come at the expense of average or top performers. Researchers have identified within these jurisdictions a commitment to holding all students to the same high standards. Equally important are the timely interventions provided to lower-performing students, avoiding the compounding effects of falling behind that cause motivation loss.[233] Personalized learning technologies also have potential to help address the achievement gap by enabling teachers to better identify students who need individualized help. The resulting one-on-one engagement can increase student motivation.[234] This is discussed further in the Personalizing Learning challenge featured as the next topic in this report section.

Implications for Policy, Leadership, or Practice

National and state policymakers are implementing initiatives to combat this wicked challenge. In the US, Delaware has found that low-SES and minority students are statistically more likely to attend schools with inexperienced teachers and high staff turnover. The state's Plan to Ensure Equitable Access to Excellent Educators for All Students uses data on student performance and educator evaluations to identify equity gaps and generate solutions.[235] Other education systems have also addressed achievement disparities through targeted funding to increase resources for low-performing students. For example, since 2014, Australia's Gonski education funding model has redirected resources to schools serving disadvantaged students to reduce their student-teacher ratios or hire specialists to address subject-specific shortcomings.[236] Similarly, Scotland's Innovation Fund supports creative, evidence-based projects to improve student outcomes in schools with high concentrations of impoverished students.[237]

Leadership efforts must pool resources and facilitate dialogs that increase awareness of these issues and move best practices into implementation in order to make progress on reducing the achievement gap. New Zealand's Investing in Educational Success initiative helps educators share ideas and scale solutions to performance challenges for disadvantaged and at-risk students. Teachers across schools are encouraged to share expertise through geographic communities of learning, while the Teacher-Led Innovation Fund supports development of innovative practices to improve learner success.[238] Additionally, organizations worldwide are engaging in concerted efforts to address this challenge. At the recent Girls' Education Forum, the United Nations Girls' Education Initiative led the charge to create the "Statement of Action to Accelerate Marginalised Girls' Education Outcomes and Gender Equality," solidifying commitments to increase access to education for girls. A global coalition of organizations signed onto the document, including UNESCO, World Bank, USAID, the African Women's Development Fund, and more.[239]

High expectations for all students can minimize disparities among student groups. Evanston Township High School near Chicago has begun placing all non-remedial students into honors classes beginning in grade 9 to help students prepare for advanced placement (AP) classes by grade 11. Students also receive additional support through programs such as Team Access and Success in Advanced Placement, or Team ASAP. These interventions have resulted in more diverse populations in AP courses and increased the number of students taking AP tests.[240] Schools can also create programs to address specific imbalances, such as the gender gap in STEM fields.[241] In addition to competing in tournaments, the Iron Maidens, an all-girls robotics team at Minnesota's Apple Valley High School, host community events to promote interest in STEM topics and lobby their state government to expand STEM education initiatives.[242]

For Further Reading

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

Gender Inequality in Learning Achievement in Primary Education (PDF)
go.nmc.org/genin
(UNESCO, 2016.) This report describes findings of differing academic performances between male and female students in Latin America and assesses potential contributing factors including learner attitude and stereotypes. Recommendations include prioritizing gender inequality issues, curriculum revisions, and changes to teacher training.

The Great German School Turnaround
go.nmc.org/germgap
(Carly Berwick, *The Atlantic*, 3 November 2015.) Germany has implemented a number of educational reforms in the last 15 years, including targeted programs for disadvantaged students and changes to the tracking system that separates students into vocational or university-bound schooling.

Measuring Inequality in a State Education Agency
go.nmc.org/pefa
(Jared Knowles, *Brookings*, 4 November 2015.) The Wisconsin Department of Public Instruction utilizes advanced statistical analysis to compare schools' racial composition against progress in closing achievement gaps over time. The resulting data set helps identify exemplars to share best practices through the Promoting Excellence for All initiative.

Stanford Education Data Archive
go.nmc.org/seda
(Stanford Center for Policy Analysis, May 2016.) The Stanford Education Data Archive (SEDA) is a massive data set with comprehensive information on US student performance, racial composition, socioeconomic status, and other factors that impact educational opportunity.

Reducing the Achievement Gap with Technology
go.nmc.org/agtech
(Max Porter, *GoGuardian*, 8 September 2015.) Technology-based instruction can help students learn more efficiently, promote learner agency, and increase outcomes for low-income students when properly integrated into the curriculum.

Technology's Role in Closing the Achievement Gap
go.nmc.org/techgap
(Dan Gordon, *THE Journal*, 28 April 2016.) Clarke County School District in Georgia has harnessed digital tools to revamp their instructional design and reduce the achievement gap. The technology initiatives have increased student engagement and promoted collaborative learning.

Personalizing Learning

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

Personalized learning refers to the range of educational programs, learning experiences, instructional approaches, and academic support strategies intended to address the specific learning needs, interests, aspirations, or cultural backgrounds of individual students.[243] The increasing focus on customizing instruction to meet students' unique needs is driving the development of new technologies that provide more learner choice and allow for differentiated content delivery. Advances such as online learning environments and adaptive learning technologies make it possible to support students' individual pathways. One major barrier is a lack of infrastructure within school systems to support dissemination of personalized learning technologies at scale. Compounding the challenge is the notion that technology alone is not the whole solution; personalized learning efforts must incorporate effective pedagogy and include teachers in the development process.[195]

Overview

Personalized learning fosters a student-centered environment, empowering them to take charge of their learning trajectories with practices that nurture habits of lifelong learning. This challenge is particularly wicked as the field has not yet reached consensus on a definition:[244] personalized learning can best be understood as an umbrella term for methods that enable students to achieve content mastery at an individualized pace.[245] The Australian national curriculum, for example, directs teachers to implement personalized learning by adjusting pedagogies to meet diverse student needs.[246] Approaches and technologies that encompass this goal include competency-based learning,[247] adaptive learning,[248] and blended learning.[249] These practices have potential to advance equity in education by enabling educators to connect with historically underserved populations, increasing motivation and engagement by helping students understand their own learning.[250] As described in the Advancing Digital Equity topic of this report, access to high-speed internet is not equally distributed across schools, hindering efforts to scale personalized learning across K-12.[251]

The wide variety of strategies and technologies contribute to the difficulty in defining metrics to measure success of personalized learning programs.[252] Frameworks can help schools envision the goals of their initiatives such as increasing student engagement, narrowing an achievement gap, or promoting teacher autonomy, and design assessments accordingly.[253] Teachers require evidence-based frameworks and professional development opportunities to effectively build curricula around individualized pathways. Another facet of this challenge is that the development of personalized learning technologies is largely being steered by suppliers, while many schools are still in the midst of identifying their needs. Textbook publishing companies are rebranding as learning management companies to offer smart products that play an active role in students' learning.[254] In this landscape, developers must work closely with educators to ensure personalized learning tools are in service of improving learning outcomes for a diverse array of students.[255]

Schools also need data and research that demonstrate efficacy of strategies in order to help them select effective supporting technologies. The philanthropic sector is working alongside major companies to fill these gaps. Facebook, for example, has partnered with California charter schools to pilot and refine a personalized learning platform; teacher feedback is continuously incorporated to improve the offering, with the goal of eventually giving the software away to other schools.[256] The Bill & Melinda Gates Foundation has funded 62 schools to implement personalized learning plans. Over a two-year period, these schools experienced greater gains than comparison schools as measured by student performance in mathematics and reading.[257] Bill Gates has also indicated that as artificial intelligence advances, these capabilities can be incorporated into personalized learning software to provide students with additional interactivity that promotes deep learning.[258]

Implications for Policy, Leadership, or Practice

While scaling personalized learning remains an elusive goal, policymakers are recognizing the value of moving from one-size-fits-all learning models. In the US, the Every Student Succeeds Act (ESSA) authorizes states and districts to implement personalized learning approaches to create more flexible learning environments. ESSA funds the use of digital learning technologies, supports student access to advanced coursework across campuses, and enables professional development opportunities for teachers.[259] Additionally, the International Association for K–12 Online Learning (iNACOL) has recently published a report detailing exemplars of state-level policies that facilitate the spread of personalized learning. Successful strategies being implemented include taskforces to pinpoint roadblocks, pilot programs and planning grants to test new instructional models, redesigned assessment and accountability standards, and the creation of multiple pathways to graduation through competency-based approaches.[260]

For personalized learning to gain traction as a movement, education leaders need to recognize best practices for adoption. Education Scotland's toolkit helps educators holistically integrate personalized learning through planning, assessment, and progress tracking processes.[261] Two online collaborative spaces were developed by the agency to advance personalized learning. Further, their National Improvement Hub contains resources, research, and assessment tools,[262] while the Digital Learning Community (DLC) serves as a collaborative space to support sharing of teaching and learning practices. The DLC also hosted National Digital Learning Week 2016, which showcased exemplar schools through video case studies and promoted discovery of innovative approaches via the hashtag #digilearnscot.[263] In the US, nonprofit LEAP Innovations has released the LEAP Learning Framework for Personalized Learning, which provides evidence-based strategies and pedagogies to help teachers understand learner needs, promote student agency, and implement mastery learning principles.[264]

Teachers can look to pilot programs and grant-funded initiatives to better understand personalizing learning in action. A project of the Infocomm Development Authority of Singapore will pilot an adaptive learning platform for mathematics instruction in area schools. Dashboards provide teachers with real-time learning analytics data on student progress on an individual and classroom level, helping instructors maximize the usefulness of in-person instruction. A content mastery approach gives students access to lessons of varying difficulty according to need, while adaptive pathways enable learner choice and promote greater engagement.[265] CICS Irving Park, a charter elementary school in Chicago, is implementing a comprehensive personalized learning program that leverages individual learner profiles, growth mindset principles, and technology-enabled learning environments to promote academic and social-emotional success for all students.[266] The school is one of seven grant recipients in the 2016 Breakthrough Schools Chicago program, a regional iteration of EDUCAUSE's Next Generation Learning Challenge.[267]

For Further Reading

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

Bill Would Allow Florida Students to Advance at Their Own Pace
go.nmc.org/floridabill
(Colleen Wright, *Tampa Bay Times*, 12 January 2016.) A bill has been introduced in both Florida's House and Senate to develop more competency-based learning programs in school districts.

Lithuanian Intelligent Future School (IFS) Project
go.nmc.org/futurelith
(Virginija Birenienne, *Scientix*, 12 November 2015.) More than 20 primary and secondary schools are serving as pilot sites for Lithuania's IFS project. For every curricular topic, learner profiles are combined with "educational intelligence" technologies to recommend a personalized suite of apps, methods, and activities for each student.

Personalized Learning Plans and Learner Profiles (PDF)
go.nmc.org/plplp
(EDUCAUSE, 2016.) Rather than making students malleable to the content, personalized learning plans and learner profiles foster a student-centered learning experience by allowing them to work with their teachers to identify goals, set the pace, and track growth.

Technology-Enabled Personalized Learning Summit (PDF)
go.nmc.org/natsum
(Jill Abbott et al., North Carolina State University, 14 May 2015.) This report summarizes findings and recommendations from a national summit. Education leaders addressed challenges surrounding personalized learning, such as bridging dispersed interdisciplinary networks of universal design for learning.

VT Agency's Tom Alderman on Mandated Personalized Learning Plans for Students
go.nmc.org/VermontPL
(Erin McIntyre, *Education Dive*, 10 November 2015.) Fall 2015 marked the rollout of Vermont's Personalized Learning Plans, a state-sponsored initiative aimed at creating a flexible learning path for students from 7th to 12th grade that incorporates individual learning processes.

What Is Personalized Learning and What Does it Mean for Kids With Disabilities?
go.nmc.org/PLdis
(Meghan Casey, National Center for Learning Disabilities, 28 April 2016.) The author makes the case for disabled students to be factored into the development of personalized learning approaches from the start. In particular, this model has the potential to build decision-making and self-advocacy for special needs students while encouraging a growth mindset.

Important Developments in Educational Technology for K-12 Education

Each of the six developments in educational technology detailed in this section were selected by the project's expert panel using the NMC 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 important developments in educational technology, 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 time-related categories — near-term developments in technology 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 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 emerging technology. The potential applications of the developments featured, specifically in the context of global K-12 education, were considered in a series of online discussions that can be viewed at k12.wiki.nmc.org/Horizon+Topics.

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. A key criterion for the inclusion of a new technology development 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 next page, to 12 technology developments 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 wiki at k12.wiki.nmc.org. 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 their use that the NMC monitors continuously. These are not a closed set, but rather are intended to provide a way to illustrate and organize emerging technologies into pathways of development that are or may be relevant to learning and creative inquiry. The list of seven categories has proven 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 of 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, make them more capable and useful, and often easier to use as well.

> **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 technologies highlighted by the 2016 K-12 Edition Expert Panel, who agree 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. As such, 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
- 3D Video
- Drones
- Electronic Publishing
- Quantified Self
- Robotics
- Tablet Computing
- Telepresence
- Wearable Technology

Digital Strategies
- Bring Your Own Device (BYOD)
- Flipped Classroom
- Location Intelligence
- Makerspaces
- Preservation/Conservation Technologies

Internet Technologies
- Cloud Computing
- Networked Objects
- Semantic Applications
- Syndication Tools

Learning Technologies
- Adaptive Learning Technologies
- Digital Badges
- Learning Analytics
- Mobile Learning
- Online Learning
- Open Licensing
- Virtual and Remote Laboratories

Social Media Technologies
- Crowdsourcing
- Online Identity
- Social Networks

Visualization Technologies
- 3D Printing
- Augmented Reality
- Information Visualization
- Virtual Reality
- Visual Data Analysis
- Volumetric and Holographic Displays

Enabling Technologies
- Affective Computing
- Artificial Intelligence
- Electrovibration
- Flexible Displays
- Machine Learning
- Mesh Networks
- Mobile Broadband
- Natural User Interfaces
- Near Field Communication
- Next-Generation Batteries
- Open Hardware
- Speech-to-Speech Translation
- Virtual Assistants
- Wireless Power

Makerspaces

Time-to-Adoption Horizon: One Year or Less

K-12 education is increasingly focused on methods to foster the development of 21st century skills in students, preparing them for the demands of the global technological economy.[268] To address the needs of the future, a growing number of classrooms, libraries, and community centers are being transformed into makerspaces, physical environments that offer tools and opportunities for hands-on learning and creation. Educators are increasingly using makerspaces and maker activities as a method for engaging learners in creative, higher-order problem-solving through design, construction, and iteration.[269] School leaders are incorporating making into the curriculum to encourage students and teachers to bring to life ideas and explore design thinking approaches. Makerspaces are also increasing student exposure to STEM subjects and technical disciplines. Learners are applying maker skills to address some of the world's pressing challenges with innovative solutions.[270]

Overview

Makerspaces are informal workshop environments located in community facilities or education institutions where people immerse themselves in creative making and tinkering activities. While many makerspaces contain sophisticated tools and technologies, they are not necessary to reap the learning benefits of making. The rise of makerspaces in education can be understood by examining the valuable skills cultivated during hands-on activities, including problem-solving, critical thinking, patience, and resilience.[271] Developing these aptitudes through creative play helps students become better equipped to meet the needs of the future workplace.[272] The maker movement and makerspaces are closely related to other educational trends such as collaborative learning, project-based learning, and student-directed learning.[273] By participating in making activities, learners can identify new passions and become more motivated as they connect classroom lessons to real-world outcomes.[274]

Governments and major companies have recognized the value of making in creating healthy economies and fostering innovation in the next-generation workforce. Amid other recent financial incentives and national policies to promote making and entrepreneurship,[275] China's Ministry of Science and Technology has pledged to invest $313 million into research and development of 3D printing technologies.[276] To help primary school educators incorporate 3D printing in the classroom, the government will also support the creation of training courses.[277] The US Department of Education's CTE Makeover Challenge will provide high schools with funding and expert design assistance to create makerspaces where students develop technical skills and explore STEM career pathways.[278] Google is also helping K-12 uncover best practices and cost-effective ways to incorporate making into the classroom. Through the Making & Science initiative, Google has partnered with Stanford University's FabLearn program to fund academic research on the efficacy of making in education and create a classroom makerspace model that meets the needs of budget-constrained schools.[279]

The maker movement also provides an opportunity for youth to apply creative skills to solve problems at local and global levels. AT&T and the Imagination Foundation recently sponsored the Inventor's Challenge, a worldwide contest for K-12 students to spur innovation within the STEAM disciplines. The winning entries included an app to help disabled populations identify accessible locations in their communities and a device that measures crops' soil moisture levels to preserve water.[280] Similarly, Hong Kong's MakerBay, a makerspace with a focus on social justice and environmentally friendly projects, offers the Impact Inventor Entrepreneurship Incubation Program. Students selected for the program on the basis of their socially conscious, technology-driven inventions receive mentorship and training in design thinking to develop their own businesses.[281]

Relevance for Teaching, Learning, or Creative Inquiry

Mobile makerspaces enable resource-challenged schools to incorporate making with limited investment and garner support among teachers, administrators, and parents. Through the Infocomm Development Authority of Singapore's Lab on Wheels initiative, more than 25,000 primary school students have written nearly 400,000 lines of code and experimented with robots, wearables, and drones aboard a retrofitted bus that acts as a traveling laboratory. The program is expanding its fleet this year to include a unit equipped with 3D printers and virtual reality headsets, as well as a bus designed to serve disabled populations.[282] After learning that many local educators had interest in maker activities but lacked time and resources to take students offsite, OpenWorks, a new community makerspace in Baltimore, created a custom van outfitted with digital fabrication tools and maker supply carts. OpenWorks Mobile will visit schools, offering technology workshops.[283]

Makerspace activities are increasingly serving as gateways to bolster interest in STEM fields. The Croatian Makers League has loaned 1,000 robots to 166 schools across Croatia and hosts monthly competitions for students to apply their skills. The privately funded program is intended to address perceived shortcomings in science instruction by helping students discover coding and programming.[284] The STEM pipeline is also strengthened by community makerspaces that serve underrepresented populations and foster mentor relationships. The University of Massachusetts Amherst's makerspace hosts youth meetups and afterschool programs to introduce girls and minority students to technology. University students serve as ambassadors for STEM disciplines, helping their younger counterparts envision themselves in these pathways.[285] Additionally, Minneapolis's Hennepin County Library's makerspace, whose membership includes high proportions of homeless youth, connects students with STEM professionals for project assistance; these relationships have led to summer internships.[286]

Schools are discovering new methods for assessing student progress and aligning curriculum standards with making activities. Alongside annual state examinations, the Albemarle County Public School system in Virginia uses student portfolios and performance tasks to measure students' development of lifelong learner competencies including data analysis, logic and reasoning, communication skills, and self-evaluation. The schools are also collaborating with nonprofit Maker Ed and the Creativity Labs at Indiana University on the Open Portfolio Project, which investigates learning and growth assessment through maker portfolios.[287] British Columbia's Surrey School District has adopted digital portfolios to capture learning outcomes in makerspaces. Using the FreshGrade app, students upload photos and videos of their work and engage in reflective thinking and writing. These continuously evolving records help both parents and teachers understand students' progress.[288]

Makerspaces in Practice

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

Building Miniature Makerspaces
go.nmc.org/minimake
At Lighthouse Community Charter School, a public school in Oakland, California, seventh and eighth graders created makerspaces for two kindergarten classes. The students employed design thinking principles, solved problems, experienced productive failure, and honed their craftsmanship skills.

Iona Presentation Primary School to Launch Makerspace
go.nmc.org/iona
In an effort to comply with Western Australia's Technologies Curriculum and other national movements aimed at encouraging students' interest in STEM education, Iona Primary School is creating a makerspace that will leverage creative technologies to allow students to engage with new subjects such as robotics and coding.

President Unveils New Initiatives During National Week of Making
go.nmc.org/makerprom
Leaders from 1,400 schools representing one million students across all US states have joined the Maker Promise initiative, pledging to support making in their schools by appointing a school maker advocate, providing dedicated space, and displaying student works.

For Further Reading

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

4 Steps to Planning a Successful Makerspace
go.nmc.org/4stepplan
(Tanya Roscorla, Center for Digital Education, 5 July 2016.) The author makes the case for the need to create "authentic" makerspaces by listing four steps an institution can follow to ensure its success.

Makerspaces Allow Students to Get Messy — And Creative
go.nmc.org/makersp
(Kelly Ng, *Today Online*, 28 October 2015.) The maker movement is reaching all corners of the world, including two primary schools in Singapore. Favorable government policy and financial support have contributed to the expansion of the movement, as school districts develop hands-on spaces to spur interest in STEM learning.

Stanford FabLearn's Paulo Blikstein On the Efficacy of Maker Ed
go.nmc.org/fablearn
(Patricia Gomes, *EdSurge*, 26 May 2016.) A pioneer in the maker movement discusses his work in leveraging interactive platforms to create new measures of success.

Online Learning

Time-to-Adoption Horizon: One Year or Less

Online learning refers to both formal and informal educational opportunities that take place through the web. Today, it is uncommon for schools to not have a web presence, and increasingly people expect for that to include learning modules and resources so that new knowledge and skills can be acquired on the go. An aspect of digital learning, which encompasses blended learning approaches, online learning has experienced a significant surge as more than 2.7 million students in the US alone are taking part.[289] Educators are becoming more comfortable testing various levels of integration in their existing classes and programs, and many believe that online learning can be an effective catalyst for thoughtful discussion on all pedagogical practice.[290] For example, online learning, especially when coupled with immersive technologies such as virtual reality, has the potential to facilitate simulations that help students better understand and respond appropriately to real-life environments and situations. Indeed, major online learning trends include more project-based learning, personalized learning, and interactivity.[291]

Overview

Online learning in schools, in the forms of blended learning, has been on teachers' radars since it was featured in the *NMC Horizon Report > 2014 K-12 Edition*. Some attribute the acceleration of online learning to widespread 1:1 deployment and the impact of the Bring Your Own Device (BYOD) movement.[292] *THE Journal* predicts that over the next two to three years, every student in the US will be equipped with a computing device.[293] With greater technology access, they assert that online learning is already a daily activity in many US schools, particularly for creating digital artifacts, accessing open educational resources, and leveraging adaptive learning tools. In developing countries such as Rwanda, Costa Rica, and India, the global initiative One Laptop Per Child aims to increase access to online learning opportunities.[294]

The variety of current online learning use cases is highlighted in the report *Keeping Pace with K-12 Digital Learning*. In the US, the researchers count hundreds of thousands of students pursuing online-only education because of homeschooling, medical issues, or engagement in sports, while millions of other students are supplementing their in-class instruction with online courses to complete advanced coursework or gain greater schedule flexibility. Some of these classes are supported by on-campus resources and others have no support from physical schools. Hybrid schools combine online and face-to-face instruction, and they are generally either offshoots of full-time online schools or derive from alternative education programs targeted towards at-risk students.[295]

As online learning matures in schools worldwide, best practices have emerged; however, research indicates that more progress is needed to improve student success rates. For at-risk Latino students in Arizona, a recent study found that they are less likely to drop out if they are engaged in fully online learning environments versus blended learning because of factors such as transportation challenges.[296] In Canada, a joint research study concerning students in rural and remote regions found that online learning was problematic without proper school-based scaffolding and recommended an onsite facilitator that could serve as a liaison between the student and other stakeholders.[297] Similarly, in the case of virtual and blended schools, researchers note that policy needs to keep pace with the changing landscape. Michigan's Learning Research Institute's study on accountability revealed that virtual schools need to establish clear communications of expectations and awareness, add student support structures, and specify teacher and mentor guidelines to improve learning outcomes.[298]

Relevance for Teaching, Learning, or Creative Inquiry

Through developments in massively open online courses (MOOCs) in the past few years and frank conversations about the mixed results, educators have quickly realized that online learning must go beyond providing access to lectures.[299] Online learning resources are now being refined and incorporated in classes in diverse ways. EdX High School, for example, offers free online test preparation and AP courses that can be applied to college credit; subjects range from CLEP exams to calculus, and can be integrated into course materials to flip a lesson plan.[300] Teachers are also taking advantage of online learning to improve their digital competencies. To help teachers become fluent in the new Australian

Technologies curriculum, the Computer Science Education Research team at the University of Adelaide launched an online course that includes introductory concepts and activities related to computational thinking at the primary and secondary levels.[301]

A major benefit of online learning is that coursework can be undertaken anywhere and at any time. For schools that face closures due to inclement weather, online learning is helping to facilitate the continuity of lesson plans. The state of Illinois experiences extreme weather regularly during the winter months, so several school districts are piloting a three-year e-learning day program when a hazardous threat or health and safety issue is posed. Students have Chromebooks to ensure that their homes would be well equipped to serve as classrooms should the need arise, with teachers and staff still reachable via email or chat.[302] Conversely, the flipped classroom structure where students engage with videos, podcasts, and interactive forums at home — as is the case at the Regents Park Christian School in Australia — has also gained popularity in recent years. Students watch video tutorials and engage with other materials online at home, freeing up class time for deeper discussions and immersive learning activities.[303]

When implemented effectively, online learning has the potential to help students graduate. Credit recovery, retaking courses to make up credits lost due to failing grades, is becoming a popular option in schools. While online credit recovery results versus traditional face-to-face instruction are mixed, there is much experimentation underway. In some schools, addressing credit recovery stimulated the development of online learning.[304] The Los Angeles Unified School District is one example of success; within three months, they were able to help 18% of their students get on a graduation track using online credit recovery.[305] iNACOL notes that online credit recovery can motivate students to learn at their own pace, integrate individualized learning preferences and interests into curricula, and address mobility issues should a student move from one school in the district to another.[306]

Online Learning in Practice

The following links provide examples of online learning in use that have direct implications for K-12 education settings:

APICE
go.nmc.org/apice
APICE is a Brazilian science and engineering online learning platform that contains rich media and learning activities. Students and teachers in basic and technical education can take two courses to learn to conduct scientific inquiry online and present their results.

Connected Learning Initiative
go.nmc.org/mitco
The Connected Learning Initiative, launched through a collaboration between MIT and others, is leveraging online learning technology to bring innovative, hands-on learning experiences to secondary students in India, specifically aiming to bridge the gap in education for those living in rural, lower-income households.

Introducing Project-Based Learning in Your Classroom
go.nmc.org/teacad
Through a five-week online course, teachers in Europe were introduced to the concept of project-based learning and learned how to implement it in their classroom. The course addressed how to collaborate effectively, facilitate student-driven activities, and properly evaluate the activities.

For Further Reading

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

Could This Digital Math Tool Change Instruction For the Better?
go.nmc.org/desmos
(Katrina Schwartz, *MindShift*, 6 April 2016.) A former math teacher has created customizable math lessons that harness the social nature of online interactions. Teachers using the platform Desmos can make slides with interactive elements that encourage more discussions between students.

Virtual Schools are Booming. Who's Paying Attention?
go.nmc.org/politico
(Darren Samuelson, *Politico*, 23 September 2015.) While the author acknowledges the benefits online learning brings the K-12 sector, including flexible learning pathways and affordability, he remains skeptical about efficacy, citing a lack in policy guidelines to ensure successful teaching systems and learning outcomes.

Web 2.0 Technologies in Alternative School Settings
go.nmc.org/web2.0
(Engin Karahan and Gillian Roehrig, *International Journal of Education in Mathematics, Science and Technology*, 28 January 2016.) This case study monitors a group of high school students' interactions and engagement on social media; the findings reveal an increase in motivation, which translates into better academic performance.

Robotics

Time-to-Adoption Horizon: Two to Three Years

Robotics refers to the design and application of robots — automated machines that accomplish a range of activities. The first robots were integrated into factory assembly lines in order to streamline and increase the productivity of manufacturing, most notably for cars. Today, the role of robots in mining, transportation, and the military has helped improve operations for industries as they perform tasks that are unsafe or tedious for humans.[307] The global robot population is expected to double to four million by 2020 — a shift that will impact business models and economies worldwide,[308] with a projected market value of $135 billion in 2019.[309] While robotics is two to three years away from mainstream adoption in K-12 education, potential uses are gaining traction for hands-on learning, particularly in STEM disciplines. Classes and outreach programs are incorporating robotics and programming to promote critical and computational thinking as well as problem-solving among students. Emerging studies also show that interaction with humanoid robots can help learners with spectrum disorders develop better communication and social skills.[310]

Overview

The development of robotics dates back as early as 350 BC when Greek mathematician Archytas wanted to better understand the mechanics of flying and built a bird that could be propelled by steam.[311] Robots are not just designed for automating activities that would require manual effort from workers; they also enable people to simulate, observe, and make sense of complex scenarios. This is especially useful for class demonstrations to help students absorb STEM concepts, as tools such as RobotsLab BOX allow teachers to manipulate robots via tablet devices.[312] Advancements in artificial intelligence, a topic featured later in this report, are greatly expanding the capabilities of these machines, making it possible for them to act intelligently, improvising and adapting their reactions and functionalities as they learn from experiences. As robots become more sophisticated in this sense, some worry that they could take away jobs from humans; however, others point to a more favorable outcome where people are freed up to concentrate on higher-level tasks.[313]

With the Robotic Industries Association reporting a 19% increase in robot orders year over year in the automotive industry alone, job opportunities across the field are growing. As such, schools are increasingly teaching programming as an integral skill, with pilots illuminating best practices for positive learning outcomes.[314] In a study conducted by researchers at Tufts University, 60 children enrolled in pre-kindergarten through second grade participated in an eight-week robotics curriculum to gain foundational knowledge and coding. Using KIWI robotics kits and CHERP programming blocks, the young students successfully programmed robots with conditional statements and reported that the activities were fun. Researchers concluded that incorporating robotics in early childhood development environments is an effective way to introduce and bolster interest in STEM learning.[315]

Robotics is also increasing access to education for students who are homebound or live in rural communities. At Commodore Perry High School, an injured student relied on a Double Telepresence robot to attend classes virtually and interact with his teachers and peers.[316] Another area where robotics has demonstrated success is administering special education, specifically for students with autism spectrum disorder (ASD). A University of Toronto study on the use of playful robots in language practice concluded that robots' low stimulus levels and predictable behaviors can help children with ASD develop communication skills.[317] Indeed, robots provide an unintimidating, approachable outlet for interactive learning. Some elementary and middle school students, for example, are using Robot4Autism's Milo, an advanced humanoid robot, to better understand emotions and demonstrate socially appropriate behaviors. Milo features facial and voice recognition technology, and is expressive and highly motivating like a real person; children working with Milo have been engaged 70-80% of the time, compared to 3-10% using traditional approaches.[318]

Relevance for Teaching, Learning, or Creative Inquiry

Robotics is a natural fit for makerspaces and other creation-centric environments where students are encouraged to invent and prototype. In addition to engaging with robots, children are learning vital computer science skills as they program them. The 2016 K-12 Edition Expert Panel has identified the embracement of coding as a key trend, as featured earlier in this report. At Admiralty Secondary School in Singapore, robotics has become an integral part of their hands-on STEM curriculum; students have built robotic arms and are planning the development of a miniature driverless car.[319] A summer camp in Iowa, NewBoCo, is teaching youth programming languages and robotics with the goal of preparing them for the technology-driven jobs of the future.[320] Similarly, Arizona State University's LEGO camp trains girls on the basics of robotics coding, bolstering their interest in STEM.[321]

Governments around the world are devising STEM education strategies that prioritize the inclusion of robots and robotics activities. The Queensland government in Australia, for example, recently mandated the addition of robotics to the school curriculum,[322] while the South Korean government piloted a seminal program where robots teach students English.[323] Major government-funded organizations are also investing in initiatives that usher in the next generation of robotics engineers. Harrington Middle School in New Jersey recently placed third in NASA's 15th annual MATE international ROV (remotely operated vehicle) competition, which invited students to design robots that could thrive in harsh ocean conditions. NASA also hosts the FIRST Robotics Competition where 9th through 12th graders solve engineering design challenges.[324]

In order for robotics to gain traction in K-12, teachers and staff need to be properly trained on how to operate any hardware and software as well as best practices for integrating it into curricula.[325] Graduate students and faculty at the Pennsylvania State University GRASP Lab are creating curriculum modules for middle school math and science teachers in the School District of Philadelphia. Supported by a grant from the National Science Foundation, the program aims to systematically train a new generation of STEM leaders within each school who can continue to generate and support robotics activities.[326] At the 2016 STEM training summer camp, hosted by the US Air Force Academy, more than 100 Colorado teachers learned coding and robotics during an intensive, three-week program.[327]

Robotics in Practice

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

Pepper Enrolls at a School in Japan
go.nmc.org/pepper
Pepper, an emotionally intelligent robot, makes history as the first of its kind to enroll in a school. Attending a Japanese high school alongside its classmates, Pepper's role is to help facilitate conversation and act as a tutor for students with disabilities.

Robotics Academy
go.nmc.org/thera
As part of their educational outreach program, Carnegie Mellon University launched the Robotics Academy to influence youth to become interested in robotics and to develop curriculum for middle and high school teachers.

Vermont Robot Rodeo
go.nmc.org/verm
Fifty schools across Vermont are participating in the inaugural Vermont Robot Rodeo. Participants can test out a cadre of robots, share best practices and learning strategies, swap robots for various projects, and learn coding basics.

For Further Reading

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

How Robotics is Transforming STEM in Elementary Schools
go.nmc.org/howrob
(June Lin, *Getting Smart*, 2 January 2016.) This article discusses the ways in which robotics is materializing in classrooms, including competitions that encourage teamwork and cross-institution collaboration. Making use of existing content and allowing students to take the lead are important tips for teachers looking to deploy robotics activities.

Kids Teaching Robots: Is this the Future of Education?
go.nmc.org/kidst
(Chris Berdik, *The Hechinger Report*, 29 April 2015.) The author explores a future learning landscape where students teach robots to actively demonstrate their knowledge acquisition and improve their higher-order thinking.

This is the Cozmo SDK: I Think it'll do for Robots what iOS did for Apps
go.nmc.org/cozmo
(Chris Davies, *Slash Gear*, 11 July 2016.) Cozmo SDK, developed by Anki, reflects a new generation of robots that is bringing advanced coding training to the mass market. This palm-sized robot is personable and entertaining as young users play games and activities that teach programming skills.

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.[328] At a basic level, this technology takes the form of 3D images that users interact with and manipulate via mouse and keyboard. 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. While VR has compelling implications for learning, to date, it has been most prominently used for military training. Thanks to advents in graphics hardware, CAD software, and 3D displays, VR is becoming more mainstream, especially in video games.[329] Today, head-mounted displays make game environments and actions more lifelike.[330] As both games and natural user interfaces are finding applications in classrooms, VR can make learning simulations more authentic.

Overview

Virtual reality delivers immersive, simulated worlds, enabling complete focus on content without distractions. Students can engage in new situations and activities in realistic settings, fostering greater knowledge retention than textbook learning.[331] A compelling method for storytelling, VR allows users to feel the experience throughout their bodies.[332] Major investments are being made in prerecorded VR content for entertainment and sports, marketing, and education. Goldman Sachs recently estimated that virtual and augmented reality entertainment revenue will reach $3.2 billion by 2025, while the education sector will attract 15 million users.[333] *The Verge* released a VR-enabled interview with First Lady Michelle Obama about her engagement with social media. The 360-degree video, overlaid with infographic-style animations, created a virtual 3D space where viewers could navigate the room and see production crew and staff.[334] Live content for virtual reality is also being actively developed; in April 2016, Medical Realities became the first to live stream a surgery in VR.[335]

The current wave of VR has permeated the mainstream, with equipment revenues projected to reach $895 million in 2016 globally. 77% of that value consists of newly launched premium devices from Oculus, HTC, and Sony.[336] The Oculus Rift and HTC Vive headsets, designed with a primary focus on gaming, video, and photo experiences, tether to computers and contain a pair of screens and lenses that generate a stereoscopic 3D image as well as sensors that monitor users' movements to adjust the images accordingly.[337] This technology is also branching out beyond gaming platforms; in the last year, smartphone users have seen an influx of low-cost VR options. The Samsung Gear VR and Google Cardboard both leverage smartphones' built-in screens and sensors. By 2025, the market for content on these platforms is projected to reach $5.4 billion.[338]

In the K-12 sector, VR is well-positioned as an educational tool, generating immersive environments for field trips,[339] with simulation and research activities serving as a prime enabler of student-centered, experiential, and collaborative learning.[340] Students are more likely to adopt VR as their digital prowess continues to increase, and they may have already experienced the technology in entertainment and gaming.[341] In a recent survey at the Consumer Electronics Show, 37% of attendees indicated that VR would find its most significant impact affording enhancements to teaching and learning, as the barriers to entry are lower than many other technology solutions.[342] Google Cardboard headsets start at $15, requiring a moderately equipped smartphone, while dedicated VR units, such as those made by Oculus and HTC, range from $300-$999, a price point many organizations still consider affordable.[343]

Relevance for Teaching, Learning, or Creative Inquiry

By fostering more engaged and authentic learning opportunities, VR can overcome shortcomings in STEM education including a reliance on theory and lack of concrete experiences.[344] An eighth-grade science class at Hampstead Hill Academy in Baltimore has embraced VR to enhance chemistry education. In collaboration with the International Neuroscience Network Foundation, Alchemy Learning has equipped the school with a virtual lab. Similar partnerships have potential to address infrastructure challenges faced by many schools that cannot support and maintain certified lab spaces.[345] Authentic experiences in VR can also stimulate students' interest in STEM careers. La Plaza, a nonprofit Latino community organization based out of Indianapolis, recently organized a STEM workshop to introduce youth to 3D graphics and virtual reality.[346] Participants interacted with experts to build and compete on virtual race courses using state-of-the-art VR headsets provided by Indiana University's School of Informatics and Computing.[347]

For most students, knowledge about global landmarks and destinations typically comes from images in books and videos on screens. Nearpod, a software company that provides a marketplace of interactive educational activities, recently enhanced their platform with VR content developed in collaboration with 360 Cities, a panoramic photography company.[348] The first publically available VR tool for schools[349] enables teachers to integrate VR components into their lessons.[350] The Knight Foundation, Marc Benioff, and Krillion Ventures will support 30-40 schools to leverage Nearpod's VR activities. One school, San Francisco's Galileo Academy of Science and Technology, incorporated the technology during a recent field trip to the Legion of Honor museum. 11th grade French students participated in a scavenger hunt, viewing Impressionist art in person as well as at Paris museums, and turned in reviews of their favorite works through the Nearpod app.[351] Galileo Academy teachers reported that students were more likely to complete assignments using the platform.

VR engages students in a fun and exciting way that increases retention. In 2015, schools in Australia, Brazil, New Zealand, the UK, and the US began collaborating with Google to beta-test Expeditions, an educational VR platform that allows users to experience over 200 virtual destinations complete with descriptions, talking points, and questions.[352] Pilot schools received training materials for teachers[353] as well as software to create new expeditions through Google Street View. At Community Consolidated School District 62 in Des Plaines, Illinois, participating students exercised curiosity and creativity, gaining insights into real-world situations.[354] As a district serving many low-income students, teachers embraced the tool to help students embark on otherwise inaccessible journeys. The beta program enabled one million students in 11 countries to participate in virtual field trips. Expeditions is now freely available on Android, with an iOS version launching soon.[355]

Virtual Reality in Practice

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

Meet the Start-Up That Wants to Send You to Space (Virtually)
go.nmc.org/SpaceVR
SpaceVR is using 360-degree, 3D video technology to immerse students into outer space in ways only previously accessible to astronauts through space travel. Launching this year, the app is compatible with multiple VR headsets and anticipates its role in educational settings as one to spur students' exploration in STEM subjects.

Virtual Reality and Augmented Reality in Education
go.nmc.org/vrarspain
inMediaStudio is a virtual and augmented reality production facility in Spain specializing in the development of digital learning. The studio aims to foster improved immersive learning, language learning, and special education opportunities.

Virtual Reality: The Next Leap to Human Learning
go.nmc.org/MindCET
A team of researchers and teachers collaborated to develop VR apps that allow high schoolers to experience the effects of physics laws and to immerse middle schoolers in challenging social situations that help them develop empathy.

For Further Reading

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

10+ Virtual Reality Apps Transforming Education
go.nmc.org/virtualapps
(Deniz Ergurel, *Haptic.al*, 10 May 2016.) With the advent of VR comes more low-risk, low-cost opportunities to immerse students into environments that are otherwise not feasible. This article highlights VR apps that are transforming the way students learn by creating opportunities that simulate a particular domain, including the human body, outer space, and ancient Egyptian temples.

Augmented and Virtual Reality in the Classroom
go.nmc.org/schrockarvr
(Kathy Schrock's Guide to Everything, accessed 25 July 2016.) An educational technologist provides an extensive, regularly updated list of tools, tips, tricks, apps, resources, and best practices for using virtual and augmented reality in the classroom.

How Virtual Reality Can Enhance STEM Education
go.nmc.org/stemvr
(Learning Liftoff, 8 February 2016.) According to the US Bureau of Labor Statistics, jobs in STEM will increase 30% by 2022. VR can help students see the practical side of STEM and encourage them to pursue STEM careers with tools, software, resources, and programs.

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.[356] The knowledge engineering that allows computers to simulate human perception, learning, and decision-making is based on access to categories, properties, and relationships between various information sets. Neural networks, a significant area of AI research, is currently proving to be valuable for more natural user interfaces through voice recognition and natural language processing, allowing humans to interact with machines similarly to how they interact with each other. By design, neural networks model the biological function of animal brains to interpret and react to specific inputs such as words and tone of voice.[357] As the underlying technologies continue to develop, AI has the potential to enhance online learning, adaptive learning software, and simulations in ways that more intuitively respond to and engage with students.

Overview

While artificial intelligence is rapidly advancing in the consumer sector, it has deep roots in the education community. The term artificial intelligence was coined in 1956 at a conference at Dartmouth College where cognitive scientists predicted that it would be successfully developed within their generation. Since the 1950s, the benchmark for machine intelligence has been the Turing Test, which requires that a human be unable to distinguish the machine from another human in natural language conversations and real-world situations.[358] Designing machines and accompanying software that could replicate human thought and behavior, however, progressed much slower than anticipated. The field was largely revived in 1997 after IBM's advent of Deep Blue, the first computer to ever beat a chess grandmaster, and again in 2011 when IBM's Watson defeated two Jeopardy! champions.[359]

In March 2016, Google's AI program AlphaGo defeated a world champion in the notoriously complex ancient Chinese game "Go." This event marked a significant milestone in the field of AI and the ability for software to engage in deep learning — algorithms that enable machines to learn from experience.[360] As the human competitor became more brazen in his gameplay, the initially peaceful AlphaGo became increasingly aggressive.[361] Indeed, many popular depictions of AI have centered around machines' abilities to compete with humans, posing existential risks to mankind; as the subject of countless science fiction works, AI is often portrayed as rendering humans obsolete or enslaving them. However, an overarching goal of this technology is to bolster productivity and engagement, better supporting the global workforce and individuals in their daily lives based on even the most subtle gestures.[362] This makes AI promising for education, especially as teaching and learning increasingly take place online.

Education institutions have become key incubators for developing new AI technology. MIT's Computer Science and Artificial Intelligence Laboratory recently created a deep learning algorithm that predicts events in videos after observing a single still clip from the footage. Scientists trained the software through exposure to 600 hours of YouTube videos so it could recognize patterns in human interactions such as shaking hands and hugging.[363] The ability for people's devices to better understand them and cater to their needs has been a major catalyst in advancing the field. Today, perhaps the most popular incarnations of AI have materialized in a growing host of virtual assistants, including Alexa, Cortana, and Siri. These voice recognition technologies take cues from mobile device owners to locate places on the internet, set calendar alerts for meetings, and much more — responding conversationally to mirror human interaction.[364]

Relevance for Teaching, Learning, or Creative Inquiry

In addition to advancements in these aforementioned famous avatars, significant developments are being made in more inconspicuous forms of artificial intelligence. Many students may not be aware of their encounters with AI as it is embedded in adaptive learning platforms, in which intelligent software personalizes learning experiences based on how each student is responding to prompts and progressing through videos and readings in virtual environments.[365] As students spend more time with the platform, the machine gets to know them better — just as a teacher or classmate would — allowing it to deliver more tailored content and recommendations over time. The adaptive learning solution Cognii, for example, leverages AI and natural language processing to identify knowledge gaps in K-12 students through short essay responses and provide real-time guidance towards concept mastery.[366] Ultimately, adaptive platforms conduct individual assessments and deliver tailored content and support, emphasizing subject areas where students need more work to achieve mastery.

As AI is at least five years away from widespread use in global K-12 education, more sophisticated learning applications are just beginning to emerge. Chatbots are one form of AI that can potentially support students as they grapple with challenges. When engaged in assignments online at home, students generally rely on email to pose questions to teachers or must wait until class. In a recent interview, Bill Gates explores the advent of chatbots as personal, virtual tutors that could facilitate more opportunities for real-time interaction and feedback.[367] As the technology becomes more refined, these AI advisors will be better equipped to interpret and respond to the subtleties of linguistics, gestures, and tones that vary in all learners. Pearson's recent report "Intelligence Unleashed" surmises that the extensive, customized feedback cultivated by AI software could eventually eliminate the need for traditional testing.[368] The authors make the case that education systems must evolve as AI advances.

Finally, AI has tremendous potential to enhance creative inquiry and informal learning. Technology behemoths including Google, Amazon, and Microsoft have already transformed the way people search for, discover, and interact with information as a result of programs that continuously track and respond to user behavior and location.[369] Advancements in image recognition and natural language processing promise to reduce the amount of time people spend finding pertinent information.[370] The days of learners poring over pages of search results to uncover the most relevant graphic design tutorial or niche scholarly work are numbered as AI recognizes users based on their previously specified interests and quickly returns fine-tuned data that will be most useful to them. In the same manner that people learn more about technology when they frequently use it, the technology itself is now constantly building its knowledge of the people who are using it.

Artificial Intelligence in Practice

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

Artificial Intelligence in Special Education
go.nmc.org/aispec
AI is increasingly being viewed as a technology that can better support children with autism spectrum disorder (ASD). In a pilot with Topcliffe Primary School in the UK, the London Knowledge Lab saw improved social skills in ASD students after they interacted with a semi-autonomous virtual boy named Andy.

Geekie
go.nmc.org/geekie
Adaptive learning is just beginning to emerge in Latin America. Students at André Urani Municipal School use Geekie, AI-enabled software, to access digital lessons that heavily incorporate videos and exercises. Geekie provides students with real-time feedback every step of the way and delivers more fine-tuned content as they progress.

Intelligent Tutoring Systems in Remote Laboratories Platform
go.nmc.org/inteltu
Researchers at the National School of Engineers of Sousse in Tunisia are investigating a web-based AI tutoring system that recognizes facial expressions as students progress through science experiments that they can access from anywhere. The goal of this technology is to improve the teaching and learning process in remote and virtual labs.

For Further Reading

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

Artificial Intelligence and Classrooms: Will It Help or Hurt?
go.nmc.org/helpor
(Matthew Lynch, *Education Week*, 28 March 2016.) The World Economic Forum predicts that by 2020, at least five million jobs worldwide will be automated. This article discusses the benefits of AI in K-12 education, including one-on-one tutoring and customized learning modules.

What Artificial Intelligence Could Mean for Education
go.nmc.org/whatai
(Anya Kamenetz, *NPR*, 16 March 2016.) The author explores current applications of AI in gameplay, citing relevant resources and positing future integrations for learning.

What's Next for Artificial Intelligence?
go.nmc.org/whatsnex
(Yann LeCun et al., *The Wall Street Journal*, 14 June 2016.) An article contributed by AI experts at Facebook, the Founders Fund, Oxford University, and Baidu delves into the next wave of deep learning.

Wearable Technology

Time-to-Adoption Horizon: Four to Five Years

Wearable technology refers to smart devices that can be worn by users, taking the form of an accessory such as jewelry or eyewear. Smart textiles also allow items of clothing such as shoes or jackets to interact with other devices. The wearable format enables the convenient integration of tools into users' everyday lives, allowing seamless tracking of personal data such as sleep, movement, location, and social media interactions. Head-mounted wearable displays such as Oculus Rift and Google Cardboard facilitate immersive virtual reality experiences.[371] Well-positioned to advance the quantified self movement, today's wearables not only track where people go, what they do, and how much time they spend doing it, but now what their aspirations are and when those can be accomplished.[372] This category also has potential to interest a variety of students in STEAM learning, as classroom activities can encompass multidisciplinary efforts of design, building, and programming.[373]

Overview

Companies including Apple,[374] Samsung,[375] and Google[376] have popularized wearable technology products that allow people to monitor data and accomplish tasks. Virtual reality-enabled headsets, a major subset of this category, are covered elsewhere in this report. CCS Insight anticipates that by 2020, the global wearable technology market will grow to $34 billion, with 411 million devices sold.[377] As wearables become more sophisticated, consumers may find increased location-specific personalization based on user behavior patterns.[378] Field leaders also predict that the future of wearables will move toward implantables, or devices directly imbedded in human bodies.[379] Meanwhile, analysts predict a continued surge in the education sector: for the next five years, Research and Markets has forecast a 46% growth rate per year in US schools' wearables adoption.[380] Technavio has pinpointed decreasing prices of wearable technologies as a growth driver alongside wearables' potential to ignite student passions and foster creative, hands-on learning activities.[381]

Recent consumer applications include devices that not only measure and record data, but also incorporate responsive assistance, helping individuals understand relationships between their bodies and surrounding environments. London startup Vinaya has introduced the Zenta, a wellness bracelet. By integrating biometric information with other apps' data, the device aims to help users identify stress triggers and balance physical and emotional needs; for example, an erratic sleeping pattern will prompt the Zenta to suggest yoga or relaxation techniques.[382] Similarly, the Muse, a sensor-equipped headband, provides real-time biofeedback and guiding audio cues to improve users' meditation practices. University researchers are using the Muse in pedagogical experiments that explore connections between brain activity and educational outcomes.[383] As wearables move toward mainstream adoption in education, K-12 classrooms could see devices that connect mental and physical variables with academic performance.

Wearable technologies help users adjust their behaviors to achieve goals. The quantified self movement has led to a number of applications aimed at improving health and performance. In the UK's Premier League, players in the Leicester City and Southampton Football Clubs wear sensors during training that collect data on movement and collisions; the teams have experienced fewer injuries since the adoption of this technology.[384] Schools are also introducing wearables into physical education (PE) classes to personalize the curriculum through real-time feedback and grades based on individual skill mastery. Students in Minnesota's Westonka School District use the Heart Zones System, a tracker that measures heart rates, speed, distance, and more. The district adopted the system to combat a drop in PE enrollment and promote fitness; educators have found that the wearables help students develop motivation and have increased engagement.[385]

Relevance for Teaching, Learning, or Creative Inquiry

Wearables can fulfill a number of achievements under Australia's new national technologies curriculum, which directs schools to create learning opportunities where students engage in design thinking and use technology to develop solutions to current and future needs.[386] Education consultancy CLWB offered STEM workshops where teachers designed and programmed smart accessories using conductive thread.[387] As discussed in the Rethinking the Roles of Teachers topic in this report, continuing professional development opportunities will help educators discover additional ideas for integrating wearables into project-based and active learning environments.[388] Schools can also look to wearables that meet the needs of flexible classroom configurations. Israel's MUV Interactive has introduced the BIRD, a Bluetooth device worn on the finger that projects interactive content from computers or smartphones onto any surface. Students can conduct presentations from anywhere in the classroom and manipulate data from their seats, and teachers can move between student groups and facilitate participatory experiences.[389]

Many leaders have recognized that wearable technologies and the maker movement provide a gateway to increase girls' interest in STEM disciplines. The female founders of Jewelbots, a company offering programmable friendship bracelets that help girls learn to code, have stated that the goal of their product is to steer more young women into STEM careers by making technology fun.[390] At the annual Fashion FUNdamentals summer program at Colorado State University's Department of Design and Merchandising, middle school girls can explore wearables, 3D printing, computer-aided design, and more.[391] Similarly, Victoria University in Australia hosted "Engineering: A Great Career for Girls," a workshop for female secondary school students that featured instruction on e-textile design followed by hands-on creation of smart garments using Arduino software. Participants showcased their works at the National Science Week Energised Fashion Runway.[392]

Educators can harness the networked power of wearables to teach students about their role in the global community. UNICEF has furnished fitness trackers to 6,000 Chicago elementary students to incentivize exercise with the ability to save lives. Students' steps are tracked as points, redeemable for food packets delivered to malnourished children worldwide. The Kid Power program, part of UNICEF's Wearables for Good campaign, will help students understand the power of collective action as well as their individual responsibilities to implement positive change.[393] Innovations in wearable technologies can also transform education for disabled students. Two university students have invented SignAloud, smart gloves that translate American Sign Language communications into speech or text via Bluetooth. The gloves can help deaf and hard-of-hearing individuals converse more seamlessly with others and provide a learning bridge to help others hone their signing skills.[394]

Wearable Technology in Practice

The following links provide examples of wearable technology in use that have direct implications for K-12 education settings:

Adidas Brings Fitness Tracking to Schoolchildren
go.nmc.org/adizone
Adidas recently collaborated with Interactive Health Technologies to develop Zone, a durable wristband that tracks student heart rates during physical education classes. Teachers can access data from a central dashboard to monitor students' progress and provide targeted instruction.

EAGER: MAKER
go.nmc.org/trackmake
The NSF has funded research using wearable technology to track youths' participation and engagement within makerspaces. Investigators hope to better understand how movement and activity correspond to the development of sustained personal interests.

Middle School Girls Design Wearable Technology
go.nmc.org/steamgirls
Tasked with designing clothing embedded with sensory capabilities, Connecticut students are getting hands-on experience learning about electrical circuits while also creating their own wearable technology.

For Further Reading

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

Personal Wearable Technologies in Education: Value or Villain?
go.nmc.org/wearabletech
(Arlene C. Borthwick et al., *Journal of Digital Learning in Teacher Education*, 2015.) The authors review ethical and privacy considerations for integrating wearable technologies into the K-12 classroom and discuss devices' potential to help educators incorporate universal design principles to meet a variety of student needs.

Wearable Technology and Schools: Where are We and Where Do We Go From Here?
go.nmc.org/wearwhere
(Brian K. Sandall, *Journal of Curriculum, Teaching, Learning, and Leadership in Education*, May 2016.) Presenting an overview of how wearable technology is being introduced into teaching and learning, this article takes a deeper look at the challenges schools must address to leverage the technology in meaningful ways.

Wearable Technology in the Classroom: What's Available and What Does it Do?
go.nmc.org/wearclass
(David Nield, *The Guardian*, 28 July 2015.) Virtual reality technologies and other immersive wearable technologies can foster creative learning experiences including digital field trips and cross-institutional collaborations.

The 2016 K-12 Edition Expert Panel

Samantha Adams Becker
Co-Principal Investigator
New Media Consortium
United States

Keith Krueger
Co-Principal Investigator
CoSN
United States

Michele Cummins
Research Manager
New Media Consortium
United States

Roger Blamire
European Schoolnet
Belgium

Arjana Blazic
IX. Gimnazija, Zagreb
Croatia

Deirdre Butler
St. Patrick's College, Dublin
Ireland

Adam Carter
Schutz American School
Egypt

Chun-Yen Chang
National Taiwan Normal University
Taiwan

Leslie Conery
Banyan Tree Partnerships, LLC
United States

Robert Craven
Computer Using Educators (CUE)
United States

Helen Crompton
Old Dominion University
United States

David Deeds
Yew Wah International Education School of Yantai
China

Michael Dezuanni
Queensland University of Technology
Australia

Claus Gregersen
Herning Gymnasium
Denmark

Lisa Gustinelli
St. Thomas Aquinas High School
United States

Matt Harris
British School of Jakarta
Indonesia

Tony Inglese
Batavia Public Schools
United States

Shafika Isaacs
Independent Digital Learning Consultant
South Africa

Mike Jamerson
Bartholomew Consolidated School Corporation
United States

Øystein Johannessen
Nordland County Council
Norway

Kevin Johnson
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Endnotes

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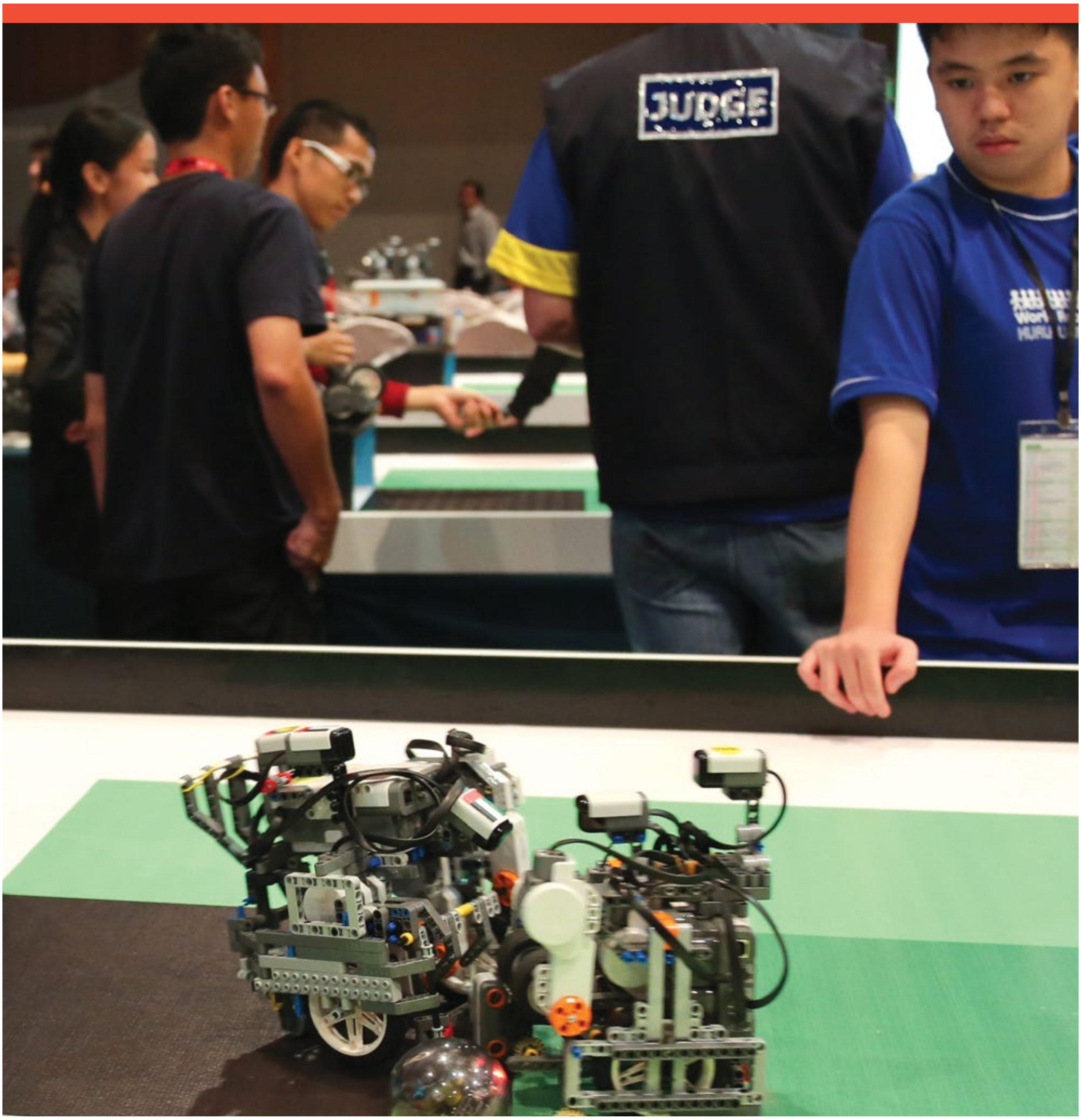

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ISBN 978-0-9977215-1-5