NMC Horizon Report > 2013 K-12 Edition

The internationally recognized *NMC Horizon Report* series and regional *NMC Technology Outlooks* are part of the NMC Horizon Project, a comprehensive research venture established in 2002 that identifies and describes emerging technologies likely to have a large impact over the coming five years in education around the globe.

Contents

Interested in these emerging technology topics? Learn more about them and other edtech insights by "liking" us on Facebook at facebook.com/newmediaconsortium and following us on Twitter at twitter.com/nmcorg.

The *NMC Horizon Report: 2013 K-12 Edition* is a collaboration between the New Media Consortium, the Consortium for School Networking, and the International Society for Technology in Education.

Citation

Johnson, L., Adams Becker, S., Cummins, M., Estrada V., Freeman, A., and Ludgate, H. (2013). *NMC Horizon Report: 2013 K-12 Edition.* Austin, Texas: The New Media Consortium.

Cover Photograph

© PhotoDisc

Inside Front and Back Cover Photograph

"A New Touch" by Wan Sin Yee, 17, Hong Kong. Submitted for the Humans in Space Youth Art Competition (www.HumansInSpaceArt.org).

Design by emgusa.com

Executive Summary

The internationally recognized *NMC Horizon Report* series and regional *NMC Technology Outlooks* are part of the NMC Horizon Project, a comprehensive research venture established in 2002 that identifies and describes emerging technologies likely to have a large impact over the coming five years in education around the globe. This volume, the *NMC Horizon Report: 2013 K-12 Edition*, examines emerging technologies for their potential impact on and use in teaching, learning, and creative expression within the environment of pre-college education. While there are many local factors affecting the practice of education, there are also issues that transcend regional boundaries and questions common to K-12 education; it was with these questions in mind that this report was created. The *NMC Horizon Report: 2013 K-12 Edition* is the fifth in the K-12 series of reports and is produced by the NMC in collaboration with the Consortium for School Networking (CoSN) and the International Society for Technology in Education (ISTE), with the generous support of HP's Sustainability & Social Innovation team.

Each of the three global editions of the *NMC Horizon Report* — higher education, primary and secondary education (K-12), and museum education — highlights six emerging technologies or practices 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.

The six technologies featured in the *NMC Horizon Report: 2013 K-12 Edition* are placed along three adoption horizons that indicate likely timeframes for their entrance into mainstream use for teaching, learning, and creative inquiry. The near-term horizon assumes the likelihood of entry into the mainstream for schools within the next 12 months; the mid-term horizon, within two to three years; and the far-term, within four to five years. It should be noted at the outset that the *NMC Horizon Report* is not a predictive tool. It is meant, rather, to highlight emerging technologies with

The six technologies featured in the *NMC Horizon Report: 2013 K-12 Edition* are placed along three adoption horizons that indicate likely timeframes for their entrance into mainstream use for teaching, learning, and creative inquiry.

considerable potential for our focus areas of education and interpretation. Each of the six is already the target of work at a number of innovative organizations around the world, and the projects we showcase here reveal the promise of a wider impact.

Near-term Horizon
On the near-term horizon — that is, within the next 12 months — are two related but distinct categories: *cloud computing* and *mobile learning*. These two sets of technologies have become a pervasive part of everyday life in much of the world, and are growing everywhere. Students have ever-increasing expectations of being able to work, play, and learn via cloud-based services and apps across their mobile devices, whenever they want and wherever they may be.

> **Cloud computing** has already transformed the way users of the Internet think about computing and communication, data storage and access, and collaborative work. Cloud-based applications and services are available to many school students today, and more schools are employing cloud-based tools

Student-specific data can now be used to customize curricula and suggest resources to students in the same way that businesses tailor advertisements and offers to customers.

all the time. Now schools are outsourcing significant parts of their infrastructure, such as email and backups, to cloud providers. Emerging devices, such as Google's Chromebooks, are designed expressly to operate in the cloud and have entered the market at affordable prices, making them viable options for one-to-one learning. These developments have contributed considerably to the adoption of cloud computing approaches at K-12 schools across the globe.

> **Mobile learning** is becoming an integral part of K-12 education, as it is increasingly common for students to own and use portable devices. With easy to use, touchscreen interfaces, even the youngest children can easily pick up a tablet or smartphone and interact with it almost immediately. Mobile devices are gateways to endless learning, collaboration, and productivity fostered by the Internet. In recent years, schools have been implementing one-to-one and BYOD strategies to take advantage of mobile technologies that are more accessible and pervasive with each passing year. One of the fastest growing facets of mobiles are mobile apps, and the momentum has yet to slow down. Scores of education companies and websites are creating

responsive programs, platforms, and curricula for mobile devices. Moreover, app development and programming is being taught to K-12 students in schools and after-school programs.

Mid-term Horizon
In the second adoption horizon, two to three years out, adoptions of two technologies that are experiencing growing interest within K-12 education are expected to pass the 20% penetration point that marks entry into mainstream practice: these are *learning analytics* and *open content*. Learning analytics is a burgeoning body of work rooted in the study of big data, which aims to use analytic techniques common in businesses to gain insights about student behavior and learning. Information derived from learning analytics can inform instructional practice in real time, as well as aid in the design of curricula and platforms that personalize education. Open content is gaining traction in K-12, with interest driven by a growing range of open source textbooks and a wider recognition of the collaborative philosophy behind creating and sharing free content.

> **Learning analytics** is the field associated with deciphering trends and patterns from educational big data, or huge sets of student-related data, to further the advancement of a personalized, supportive system of K-12 education. Preliminary uses of student data were directed toward targeting at-risk learners in order to improve student retention. The widespread adoption of learning and course management systems has refined the outcomes of learning analytics to look at students more precisely. Student-specific data can now be used to customize curricula and suggest resources to students in the same way that businesses tailor advertisements and offers to customers. Schools are already employing analytics software to make the college advising process more efficient and accurate, while researchers are developing mobile software to coach students toward productive behaviors and habits that will lead to their success.

> **Open content** is the current form of a movement that began a decade ago, when universities such as MIT began to make their course content freely available.

Twelve years later, schools are sharing a significant amount of curricula, resources, and learning materials. There is a growing variety of open content from K-12 organizations and schools, and in many parts of the world, open content represents a profound shift in the way students study and learn. Far more than just a collection of free online course materials, the open content movement is increasingly a response to the rising costs of education, the desire to provide access to learning in areas where such access is difficult, and an expression of student choice about when and how to learn.

Far-term Horizon

On the far-term horizon, set at four to five years away from entry into the mainstream of practice, are *3D printing* and *virtual and remote laboratories*. 3D printing provides a more accessible, less expensive, desktop alternative to industrial forms of rapid prototyping. Many of the discussions surrounding 3D printers stem from the Maker culture, an enthused community of designers, programmers, and others that brings a do-it-yourself approach to science and engineering. Virtual and remote laboratories provide students with the opportunity to conduct scientific experiments as often as they like, from whatever device they are using. In virtual laboratories, the equipment is simulated, while remote laboratories encompass high-caliber apparatuses that are housed in central locations. These technologies are several years away from mainstream use, but already it is clear that their impact will be significant, despite the lack of well-documented K-12 project examples. The high level of interest and investment in both areas are clear indicators that they are worth following closely.

> **3D printing** has become much more affordable and accessible in recent years in large part due to the efforts of MakerBot Industries. Founded in 2009, this company has promoted the idea of openness by offering products that can be built by anyone with minimal technical expertise. With MakerBot Replicators selling in the range of $1,500 to $3,000, it now only requires a small financial investment to own a 3D printer. Moreover, websites such as Thingiverse offer source files that anyone can use to print objects

without original designs, and mobile apps, such as 123D Catch, make it possible for anyone to create their own 3D images of real objects for printing. Schools are using 3D printers to illuminate the design process, build rapid prototypes, and create models that demonstrate concepts in curricula.

> **Virtual and remote laboratories** leverage wireless networks, mobile devices, and cloud-based software to make scientific experiences more accessible for schools that lack fully equipped labs. In many ways, virtual and remote labs have benefits that hands on environments do not; in virtual and remote environments, an experiment can be conducted numerous times with greater efficiency and precision. Granted 24/7 access and with more room to make mistakes, students can spend more time making scientific measurements and engaging in laboratory practices. Many schools are taking advantage of these virtual interfaces and simulations to provide students with authentic scientific experiences without the associated costs of building and maintaining physical lab spaces.

To create the report, an international body of experts in education, technology, and other fields was convened as an advisory board. Over the course of just a few weeks in the Spring of 2013, the 2013 Horizon.K12 advisory board came to a consensus about the topics that appear here in the *NMC Horizon Report: 2013 K-12 Edition*. The examples and readings under each topic area are meant to provide practical models as well as access to more detailed information.

Each of these technologies is described in detail in the main body of the report, where a discussion of what the technology is and why it is relevant to teaching, learning, or creative inquiry can also be found. Our research indicates that all six of these technologies have clear and immediate potential for teaching and learning, and this report aims to document that in a simple and compelling fashion.

The group engaged in discussions around a set of research questions intended to surface significant trends and challenges and to identify a wide array of potential

technologies for the report. This dialog was enriched by an extensive range of resources, current research, and practices that drew on the expertise of both the NMC community and the communities of the members of the advisory board. These interactions among the advisory board are the focus of the *NMC Horizon Report:*

Schools are using 3D printers to illuminate the design process, build rapid prototypes, and create models that demonstrate concepts in curricula.

2013 K-12 Edition research, and this report details the areas in which these experts were in strong agreement. The precise research methodology employed is detailed in the closing section of this report.

The advisory board of 55 technology experts spanned 18 countries this year, and their names 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 are going to have a significant impact on the practice of primary and secondary education around the globe over the next five years. The key trends driving interest in their adoption, and the challenges schools and school systems will need to address if they are to reach their potential, also represent their perspective, and are the focus of the next sections of the *NMC Horizon Report: 2013 K-12 Edition,* where each is detailed in the context of schools, teaching, and learning.

To make comparisons easy, the report's format is consistent from year to year and edition to edition, and opens with a discussion of the trends and challenges identified by the advisory board as most important for the next five years. The format of the main section of this edition closely reflects the focus of the NMC Horizon Project itself, centering on the applications of emerging technologies — in this case for K-12 settings.

Each section is introduced with an overview that describes what the topic is, followed by a discussion of the particular relevance of the topic to teaching, learning, and creative inquiry in K-12 education. Several concrete examples of how the technology is being used are given.

Finally, each section closes with an annotated list of suggested readings and additional examples that expand on the discussion in the report. These resources, along with a wide collection of other helpful projects and readings, can all be found in the project's open content database that is accessible via the NMC Horizon EdTech Weekly App for iOS (go.nmc.org/ios) and Android devices (go.nmc.org/android). All the background materials for the *NMC Horizon Report: 2013 K-12 Edition*, including the research data, the preliminary selections, the topic preview, and this publication, can be downloaded for free on iTunes U (go.nmc.org/itunes-u).

Key Trends

The technologies featured in each edition of the *NMC Horizon Report* are embedded within a contemporary context that reflects the realities of the time, both in the sphere of K-12 education and in the world at large. To ensure this context was well understood, the advisory board engaged in an extensive review of current articles, interviews, papers, and new research to identify and rank trends that are currently affecting teaching, learning, and creative inquiry in K-12 education. Once detailed, the list of trends was then ranked according to how significant each was likely to be for K-12 education in the next five years. Those listed here had significant agreement among the advisory board members, who considered them to be key drivers of educational technology decisions over that time. They are listed here in the order in which the advisory board ranked them.

1 Education paradigms are shifting to include online learning, hybrid learning, and collaborative models. Students already spend much of their free time on the Internet, learning and exchanging new information — often via their social networks. Institutions that embrace face-to-face/online hybrid learning models have the potential to leverage the online skills learners have already developed independent of academia. Online learning environments have distinct advantages over physical campuses, including opportunities for greater collaboration while equipping students with stronger digital skills. Hybrid models, when designed and implemented successfully, enable students to travel to campus for some activities, while using the network for others, taking advantage of the best of both environments.

2 Social media is changing the way people interact, present ideas and information, and communicate. More than one billion people use Facebook regularly; other social media platforms extend those numbers to nearly one third of all people on the planet. Educators, students, and even the general public routinely use social media to share current events, opinions, and articles of interest. Likewise, scientists and researchers use social media to keep their communities informed of new developments. The fact that all of these various groups are using social media speaks to its effectiveness in engaging people. The impact of these changes in scholarly communication and on the credibility of information remains to be seen, but it is clear that social media has found significant traction in almost every education sector. It is not uncommon, for example, to see teachers using Facebook, Twitter, Google Hangouts, and other platforms to connect with their students.

3 Openness — concepts like open content, open data, and open resources, along with notions of transparency and easy access to data and information — is becoming a value. As authoritative sources lose their importance, there is need for more curation and other forms of validation to generate meaning in information and media. "Open" has become a term often applied in very different contexts. Often mistaken to mean "free," open education advocates are working towards a common vision that defines "open" more broadly — not just free in economic terms, but educational materials that are freely copiable, freely remixable, and free of barriers to access, sharing, and educational use.

4 As the cost of technology drops and school districts revise and open up their access policies, it is becoming more common for students to bring their own mobile devices. A growing number of schools are launching "Bring Your Own Device" (BYOD) programs so that students can use the devices they

already own in class. This is happening as a result of how BYOD impacts budgets; schools can spend less money on technology overall if they focus their efforts on equipping the students who cannot afford their own devices. The relative new interest in BYOD programs has been accompanied by an attitude shift

The relative new interest in BYOD programs has been accompanied by an attitude shift as schoolteachers and staff better understand the capabilities of smartphones and other devices.

as schoolteachers and staff better understand the capabilities of smartphones and other devices that, unfortunately, still remain banned on many school campuses.

5 **The abundance of resources and relationships made easily accessible via the Internet is challenging us to revisit our roles as educators.** Institutions must consider the unique value that schools add to a world in which information is everywhere, and generally free. In such a world, sense-making and the ability to assess the credibility of information are paramount. Mentoring and preparing students for the world in which they will live and work is again at the forefront. K-12 institutions have always been seen as critical paths to educational credentialing, but challenges from competing sources are redefining what these paths can look like.

Significant Challenges

Any discussion of technology adoption must also consider important constraints and challenges, and the advisory board drew deeply from a careful analysis of current events, papers, articles, and similar sources, as well as personal experience, in detailing a long list of challenges schools face in adopting any new technology. The most important of these are detailed below, but it was clear from the discussions with the experts that behind the challenges listed here is also a pervasive sense that local and organizational constraints are likely the most important factors in any decision to adopt — or not to adopt — a given technology.

Even K-12 institutions that are eager to adopt new technologies may be constrained by school policies, the lack of necessary human resources, and the financial wherewithal to realize their ideas. Still others are located within buildings that simply were not designed to provide the radio frequency transparency that wireless technologies require, and thus find themselves shut out of many potential technology options. While acknowledging that local barriers to technology adoptions are many and significant, the advisory board focused its discussions on challenges that are common to the global K-12 community as a whole. The highest ranked challenges they identified are listed here, in the order in which the advisory board ranked them.

1 Ongoing professional development needs to be valued and integrated into the culture of the schools. There is immense pressure placed on teachers to incorporate emerging technologies and new media in their classrooms and curriculum. All too often, when schools mandate the use of a specific technology, teachers are left without the tools (and often skills) to effectively integrate the new capabilities into their teaching methods. The results are that the new

investments are underutilized, not used at all, or used in a way that mimics an old process rather than innovating new processes that may be more engaging for students.

2 Too often it is education's own practices that limit broader uptake of new technologies. Resistance to change simply reflects comfort with the status quo. In many cases, experimentation with or piloting of innovative applications of technologies are often seen as outside the role of teacher or school leader, and thus

In order for students to get a well-rounded education with real world experience, they must also engage in more informal in-class activities as well as experience learning outside the classroom.

discouraged. Changing these processes will require major shifts in attitudes as much as they will in policy.

3 New models of education are bringing unprecedented competition to traditional models of schooling. Across the board, institutions are looking for ways to provide a high quality of service and more opportunities for learning. MOOCs are at the forefront of these discussions, and have opened the doorway to entirely new ways of thinking about online learning. K-12 institutions are latecomers to distance education in most cases, but competition from specialized charter schools and for-profit providers has called attention to the needs of today's students,

especially those at risk. USC Hybrid High School in downtown Los Angeles is a good example; its mission is to graduate 100% of its students to be socially and academically prepared for success in college and the workplace. To that end, the school incorporates a flexible schedule, highly integrated online components, and personalized learning plans to keep students engaged and focused on success.

4 K-12 must address the increased blending of formal and informal learning. Traditional lectures and subsequent testing are still dominant learning vehicles in schools. In order for students to get a well-rounded education with real world experience, they must also engage in more informal in-class activities as well as experience learning outside the classroom. In most schools, students are not encouraged to do this, nor to experiment and take risks with their learning, but new models are finding their way into practice. The "flipped classroom," for example, uses educational materials on the Internet as a primary content strategy. New concepts and material are initially studied outside of school, thus preserving class time to refine mastery with discussions, collaborations with classmates, problem solving, and experimentation. The approach is not a panacea, and designing an effective blended learning model is key, but the growing success of the many non-traditional alternatives to schools that are using more informal approaches indicates that this challenge is being confronted.

5 The demand for personalized learning is not adequately supported by current technology or practices. The increasing demand for education that is customized to each student's unique needs is driving the development of new technologies that provide more learner choice and control and allow for differentiated instruction, but there remains a gap between the vision and the tools needed to achieve it. The notion that one-size-fits-all teaching methods are neither effective nor acceptable for today's diverse students is generally accepted among K-12 educators.

6 We are not using digital media for formative assessment the way we could and should. Assessment is an important driver for educational practice and change, and over the last years we have seen a welcome rise in the use of formative assessment in educational practice. However, there is still an assessment gap in how changes in curricula and new skill demands are implemented in education; schools do not always make necessary adjustments in assessment practices as a consequence of these changes. Simple applications of digital media tools, like webcams that allow non-disruptive peer observation, offer considerable promise in giving teachers timely feedback they can use.

These trends and challenges are a reflection of how technology has come to impact almost every aspect of our lives, and indicative of the changing nature of the way we learn, communicate, access information, and assess student performance. This is certainly true across the developed world, but is also starting to be seen even in very remote or economically disadvantaged areas.

Taken together, these environmental realities provided the advisory board a frame through which to consider the potential impacts of the nearly 50 emerging technologies and related practices that were analyzed and discussed for possible inclusion in this edition of the *NMC Horizon Report* series. Six of those were chosen through successive rounds of ranking and have been identified as "Technologies to Watch." They each have been placed on one of three possible time-to-adoption horizons that span the coming five years, and are detailed in the main body of the report, which follows.

Cloud Computing

Time-to-Adoption Horizon: One Year or Less

loud computing refers to expandable, on-demand services and tools that are served to the user via the Internet from specialized data centers and do not live on a user's device. Cloud computing resources support collaboration, file storage, virtualization, and access to computing cycles. The number of available applications that rely on cloud technologies has grown to the point that few institutions do not make some use of the cloud, whether as a matter of policy or not. Clouds, especially those supported by dedicated data centers, can be public, private, secure, or a hybrid of any or all of these. Increasingly school CIOs see the cloud as a solution for storage, backup, software as a service (SaaS), and more, as well as a way to reduce IT overhead costs. A growing need is for cloud services to be delivered in a secure manner, especially in jurisdictions where privacy is a critical concern. Private cloud computing — essentially specialized data centers built to provide users highly secure access to data — solves these issues by providing common cloud solutions in secure environments. Hybrid clouds provide the benefits of both types. Whether connecting at home, work, school, on the road, or in social spaces, nearly everyone who uses the network relies on cloud computing to access or share their information and applications.

Overview

Over the past few years, cloud computing has been firmly established as an efficient way for businesses — and increasingly schools — to protect data, develop applications, deliver software and online platforms, and to collaborate. Cloud-based services provide a range of solutions that address a wide variety of needs related to infrastructure, software, and security. By means of virtualization, cloud computing providers can deliver fully-enabled virtual computing environments of almost any scale that can be accessed from any connected device, seamlessly and on demand.

Cloud services are grouped into three categories: 1) infrastructure-as-a-service, commonly referred to as virtualization — virtual machines, bandwidth, and storage, all scalable as needed; 2) platform-as-a-service (PaaS), the environment for developing and delivering applications; and 3) software-as-a-service (SaaS), software designed to meet specific needs of an organization.

As more individuals use cloud-based sharing services such as Dropbox and Google Drive in their personal lives, cloud computing has become widely recognized as a means of improving productivity and expanding collaboration in education, while alleviating the financial burdens imposed by server-based infrastructures. Cloud services specifically cut the cost and time required for server maintenance, and offer support for new tools that foster best computing practices for easy sharing and mobility.

In 2011, cloud computing was listed in the near-term horizon, primarily because of the way it has become an essential part of collaboration in both schools and the workplace. This year, the placement of cloud computing on the near-term horizon for a second time underscores that the impact of this technology continues to unfold in new and expanding ways. Its rapid integration into our everyday lives — from technology infrastructure to communication exchanges to the many apps and resources used for informal learning — has only accelerated institutional interest in cloud computing. At the same time, it is clear that barriers to adoption in schools are being met in a variety of ways, especially concerns that the cloud is not sufficiently safe for sensitive data. The development of private and hybrid clouds leverages the benefits of the underlying

convenience of cloud computing to create a system that is scalable, secure, and safe.

As the mobile internet has expanded, new devices such as Google's Chromebooks that are designed expressly to operate in the cloud have entered the market, and at

The placement of cloud computing on the near-term horizon for a second time underscores that the impact of this technology continues to unfold in new and expanding ways.

price points that make them instantly competitive in the race to one-to-one computing. Similarly, new tablets and smartphones take full advantage of the cloud and bring considerable power to these increasingly capable devices. As districts strengthen their infrastructures to support one-to-one learning and BYOD deployments, they are also using the cloud to make it easy for students and teachers to access district resources from any device. New cloud-based administrative solutions are intended to decrease teachers' workloads by eliminating paperwork while making it easier for them to keep track of student progress and data securely from any device.

Relevance for Teaching, Learning, or Creative Inquiry

According to CDW-G's 2013 *State of the Cloud Report,* 42% of K-12 schools and organizations surveyed are currently implementing some form of cloud computing solution; the top uses are for storage, conferencing and collaboration, and for office suite management. Cloud-based offerings such as email, video and other hosting services; subscription-based software tools; and a wide choice of collaborative applications take the pressure off of schools to continually update their machines and software.

One of the most common uses of cloud computing technology in the classroom over the past couple years

has been the integration of cloud-based tools such as Google Apps into the K-12 curriculum. Web-based applications work in any browser and offer a device-agnostic place for project materials, submissions, and assignments. Today's cloud infrastructure includes a wide array of tools and services that make it easy for anyone to share media and materials. Khan Academy, for example, was among the first educational initiatives to take advantage of the incredible infrastructure behind YouTube to host its video lessons for free.

Additionally, many distance-learning programs are implementing cloud computing solutions to accommodate increasing enrollment and provide more media-rich resources to students in remote or rural areas. In Wisconsin, for example, over 2,000 students across 39 K-12 districts are enrolled in dozens of online courses that make use of a cloud-based video management system that automates uploading. The system makes it easy for teachers to create a video-based curriculum or implement a flipped classroom model. go.nmc.org/ensem

Cloud-based solutions for schools have grown more intricate as technology providers collaborate on systems that prepare students for the modern workforce. In the Prince George County Public School System in Maryland, for instance, high school students and teachers are piloting a STEM Innovation Cloud, designed by Lockheed Martin in partnership with Cisco Systems, Inc., that will create equitable access to STEM resources. The STEM curriculum will include videos of discovery-based classroom experiences, as well as career simulations that can be delivered via mobile devices. go.nmc.org/lock

Similarly, virtual laboratory sites can be hosted in the cloud, increasing the accessibility of lab equipment to under-resourced districts. iLabCentral, for example, is home to more than 7,000 experiments that can be accessed from any device (go.nmc.org/ilabs). The emergence of cloud-centric mobile devices such as Google's Chromebook, an inexpensive laptop that relies on ubiquitous connectivity and cloud-based software and storage, is ushering in a new era of equity and access.

In April 2013, Malaysia announced its national plan

to deploy Google's Chromebooks in primary and secondary schools throughout the country. They join the Philippines as a nation that has embraced Chromebooks' cloud-based software and hardware to reform their educational system. Currently, more than 3,000 schools across the world are exclusively employing Chromebooks, a technology strategy that makes the web crucial for learning. go.nmc.org/mala

In addition to formal learning experiences, cloud computing enables rich informal learning opportunities. Sugata Mitra, 2013 TED Prize winner and scientist, outlined a compelling vision of this era in his recent TED Talk (go.nmc.org/sugata). Mitra's observation that children can essentially organize their own learning led to the notion of "Schools in the Cloud," which are essentially learning facilities in impoverished regions of the world that can be operated entirely in the cloud, including lights, locks, and infrastructure. These schools could be a low-cost supplement to formal education, and a place where children can pursue their own inquiries.

A sampling of applications of cloud computing across disciplines includes the following:

> **Language.** The cloud-based Electronic Learning Organizer helps language teachers produce and share digital learning objects and activities for their students. The learning objects are created by the teacher, or assembled from a resource repository created by other teachers in the network: go.nmc.org/elo.

> **Science.** California State University Northridge launched the Computer Supported Collaborative Science initiative to help science teachers in high-need Los Angeles area schools to engage students in authentic research experiences through the use of cloud-based tools: go.nmc.org/sci.

> **Social Studies.** Powered by cloud computing, the Global Curriculum Project allows students to participate in a virtual exchange program with schools across five different countries. Students select and explore their own topics, including cuisine and ambitions: go.nmc.org/curric.

Cloud Computing in Practice

The following links provide examples of cloud computing in use in K-12 education settings:

Chromebooks and One-to-One
go.nmc.org/chrmbk
At South Bay Middle School in California, a new Chromebook one-to-one policy has been implemented. School administrators cite that the accessibility of Google's cloud-based tools have made learning and assignment grading a nearly paperless process.

ClassLink at Buffalo Public Schools (PDF)
go.nmc.org/buf
Buffalo Public Schools in New York use a cloud-based environment called ClassLink that allows students, parents, and faculty to access a shared desktop from anywhere or any device with Internet access.

Edmonton Public School Google Apps & Privacy
go.nmc.org/edm
In Canada, Edmonton Public Schools have created an informative page on Google's privacy policy and how this affects students and the school's use of the Google Apps. Other schools looking to integrate Google Apps can access their website to get information on email privacy and security tips for various grade levels.

FlexiSAF School Management System
go.nmc.org/gafrica
Using the Google Web Toolkit, Nigerian developers converted an administrative management application from its desktop version to a web-based version in order to help K-12 administrators efficiently manage school records. The new software is currently impacting 70 public and 30 private schools in Nigeria and will soon be offered to other African countries.

Middle School Using Cloud Computer for Down-to-Earth Education
go.nmc.org/hobart
At Hobart Middle School in Indiana, students use cloud-based services and tools, such as Google Drive, Facebook, and Twitter, to keep up with their classwork at home. Using these platforms and others has helped teachers provide students with real-time feedback.

Moving to Cloud Computing at St Thomas's Church of England Primary School
go.nmc.org/stthom

A school in Northwest England has transitioned to cloud computing for their technological infrastructure, making it possible for students to connect to Internet applications within seconds. The entire research and methodology of the move is documented via their Wikispace.

42% of K-12 schools and organizations surveyed are currently implementing some form of cloud computing solution.

Multiseat Computing at Lakeside School, Costa Rica
go.nmc.org/lakeside

To increase the reach and power of their computers, the founders of Lakeside School in Costa Rica selected a Linux cloud-based solution that maintains an entire lab of workstations using just three computers. As a result of the new system, the school will save money on hardware and support costs, as well as enough energy to power 21 homes over three years.

Nokia Mobile Mathematics
go.nmc.org/momaths

Already implemented by 200 schools in South Africa, this project by Nokia offers free math lessons for grades 10-12 using a cloud service that can be accessed via web browser on any computer or mobile device. Students can test themselves continuously and receive instant feedback on their answers — even outside of the classroom.

St. Columba Anglican School and Chromebooks
go.nmc.org/colum

St. Columba Anglican School in Port Macquarie is one of the first schools in Australia to incorporate Chromebooks as part of its transition to the cloud to complement its BYOT policy. For their pilot, they have purchased 60

Chromebooks to be shared among students in grades K-5.

For Further Reading

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

Cloud Computing to Make Up 35% of K-12 IT Budgets in 4 Years
go.nmc.org/bud

(David Nagel, *The Journal*, 19 February 2013.) According to a study released by CDW-G, storage is the top application of cloud computing used in K-12 education, followed by conferencing, collaboration, and finally office and productivity tools. K-12 schools expect to save 20% of the IT budget in the coming year by using cloud services and the costs will consume 35% of the entire IT budget.

Cloudy With a Chance of Data
go.nmc.org/govcl

(Richard Culatta, U.S. Department of Education, 17 April 2013.) The Deputy Director of the Office of Educational Technology describes what it means to store data in the cloud. He gives a thorough overview of how the cloud works and touches on the legal issues regarding protecting student data.

Districts Move to the Cloud to Power Up, Save Money
go.nmc.org/dis

(Mike Bock, *Education Week*, 6 February 2013.) This article covers how the Chicago public school system is using Google Apps to reduce financial burdens. They are also making use of free programs, including a cloud-based remote laboratory, instead of purchasing expensive science equipment.

Industry Perspective: Accelerate Education With Open Source Cloud Techs
go.nmc.org/accel

(David Egts, *Government Technology*, 26 February 2013.) This article cites cloud computing as instrumental to the evolution of online learning, including massive open online courses and video lecture platforms such as the Khan Academy.

Microsoft Office 365 or Google Apps for Education: Which Way Do You Go?
go.nmc.org/mic
(David Weldon, *The Journal*, 3 April 2013.) Two education systems adopted different cloud platforms to provide remote access, save money in licensing fees, and help students share their work. The state of Oregon is two years into the first statewide rollout of Google Apps for Education, while last year, the Clarksville-Montgomery County School System became the first countywide school district to launch Microsoft Office 365 for Education.

Schools Move Security to the Cloud
go.nmc.org/sec
(Steve Zurier, *EdTech Magazine*, 13 February 2013.) The Kings County Office of Education in California along with Pennsylvania Cyber Charter School have decided to implement SaaS solutions, allowing IT to centrally manage security of an array of devices often accessed remotely. Such cloud-based services also allow multiple devices to be updated through one central action.

What Is a Unified Cloud, and Why Are Schools Choosing to Build Them?
go.nmc.org/unify
(Wylie Wong, *EdTech Magazine*, 2 April 2013.) Several districts and schools have adopted unified cloud strategies in order to increase efficiency and gain easier access to resources, aligning with the trends indicated in the CDW-G 2013 *State of the Cloud Report*.

Mobile Learning

Time-to-Adoption Horizon: One Year or Less

eople increasingly expect to be connected to the Internet and the rich tapestry of knowledge it contains wherever they go. Mobile devices, including smartphones and tablets, enable users to do just that via cellular networks and wireless power. The growing number of mobile subscribers, coupled with the unprecedented evolution of these devices, has opened the door to myriad uses for education. Learning institutions all over the world are exploring ways to make their websites, educational materials, resources, and opportunities all available online and optimized for mobile devices. The most compelling facet of mobile learning right now is mobile apps. Smartphones and tablets have redefined what we mean by mobile computing, and in the past four to five years, apps have become a hotbed of development, resulting in a plethora of learning and productivity apps. These tools, ranging from annotation and mind-mapping apps to apps that allow users to explore outer space or get an in-depth look at complex chemicals, enable users to learn and experience new concepts wherever they are, often across multiple devices.

Overview

After years of anticipation, mobile learning is positioned for near-term and widespread adoption in schools. Tablets, smartphones, and mobile apps have become too capable, too ubiquitous, and too useful to ignore, and their distribution defies traditional patterns of adoption, both by consumers, where even economically disadvantaged families find ways to make use of mobile technology, and in schools, where the tide of opinion has dramatically shifted when it comes to mobiles in schools.

At the end of 2012, the mobile market consisted of over 6.5 billion accounts, and subscriptions are expected by

ICT's *Facts and Figures* report to equal close to the world's population by the end of 2013. This equates to about 3.4 billion users, or nearly one of every two people on the planet. The portability of mobile devices, coupled with increasingly fast web and cellular connectivity, make mobiles extremely conducive to productivity and learning. This year, mobile traffic on the Internet is expected to surpass desktop traffic. The Internet itself is becoming a mobile network.

Furthermore, the incredible diversity of mobile apps has expanded the capabilities of mobile devices enormously — and people love them. ABI Research estimated mobile users will download 70 billion apps in 2013 across smartphones and tablets — or more than 10 apps per each human being on Earth. In April 2013, 148Apps reported that educational apps were the second most downloaded in iTunes of all of the categories — surpassing both entertainment and business apps in popularity. One of the fastest growing categories is apps for very young learners. A special report, *iLearn II: An Analysis of the Education Category on Apple's App Store*, noted that over 80% of educational apps specifically target children.

Mobiles are also a significant distribution channel for magazines and e-books, which has made the platform appealing to major education publishers. Pearson, among many others, is designing textbooks and other resources with interactive elements optimized for mobile devices. Tablets, such as the iPad, Samsung Galaxy, Nexus, and Surface, are exceptionally effective at displaying e-books and other visual content. They serve as conveniently sized video players with instant access to an enormous library of content; real-time two-way video conferencing tools; increasingly high-resolution still and video cameras; fast, easy email and web browsers; and rich, full-featured game platforms. A

swipe, a tap, or a pinch allows the user to interact with the device in completely new ways that are so intuitive and simple they require no manuals or instructions.

Ultimately, one of the biggest appeals of mobiles is that they naturally encourage exploration — a notion that is easily demonstrated by placing a device in the hands of a small child. Whether it's connecting with new people via social media or discovering local resources recommended by an app, mobiles provide people with constant opportunities to act upon their curiosities and expand their knowledge.

Relevance for Teaching, Learning, or Creative Inquiry

Because of their portability, flexibility, and natural, intuitive interfaces, mobiles are especially enticing to schools, and a growing number of them have turned to tablets as a cost-effective strategy for one-to-one learning — a systemic solution in which every student is provided a device that can be used to support learning in and outside of the classroom. In many regions of the world, students come to class already familiar and comfortable with the technology. At the end of 2012, the Daily Mail reported that 75% of ten-year-olds in the UK, for example, own a mobile device, and the global average is approaching 50%.

In a one-to-one pilot at Justin-Siena High School in California, every student will be receiving an iPad during fall orientation (go.nmc.org/Justin). Students have expressed excitement about having fewer textbooks to carry and teachers are looking forward to the improved Internet access; they will no longer have to make reservations and confine learners to the computer lab. One teacher plans to have students use the iPads to record themselves during presentations to become better public speakers.

Consumer Reports recently cited that 60% of U.S. parents of children ages eight to 12 have provided their children with mobile phones. In many educational settings, the primary challenge for making use of these devices is the schools' mobile use policies, but this is changing quickly. A key driver of that change is the move to BYOD ("Bring Your Own Device"), which many schools are already

piloting. BYOD addresses many interesting pedagogical goals, but also a key financial issue — the lack of funds to support one-to-one learning. BYOD makes one-to-one easier by simply leveraging the devices that students already have.

In just one of many possible examples, the School Board of Fayette County Schools in Kentucky has approved BYOD in all secondary schools after successful junior high and high school pilots in 2011 and 2012. The devices were found to bring out each student's unique abilities, and

Tablets, smartphones, and mobile apps have become too capable, too ubiquitous, and too useful to ignore.

foster more collaboration and better communication. Students were more engaged with each other and in the material being taught. go.nmc.org/fay

According to current ASTD research, the top uses of mobiles in learning are easily accessing reference materials, supporting student performance, and watching videos. Furthermore, when they are equipped with an array of apps, cameras, sensors, and other built-in tools, students are able to explore specific locations and record their experiences via photographs, videos, and audio recordings. For example, Greenridge Primary School piloted the Singapore Zoo's River Safari app, which uses location-based and image recognition technology to better acquaint students with surrounding wildlife (go.nmc.org/lgork). Similarly, at Ryan Elementary in Colorado, students use iPads to go on digital scavenger hunts using Google Earth, to create digital stories using cartoon apps. A teacher there reports she likes the way the iPads encourage students to troubleshoot learning obstacles and collaborate with each other. go.nmc.org/Rya

While one-to-one and BYOD programs are still relatively new, there are a number of organizations and institutions dedicated to exploring their outcomes and dreaming up new uses for mobile devices. UNESCO's

Mobile Education Lab is a creative organization that promotes the discovery and invention of digital content for exploring the potential of mobile technology in education (go.nmc.org/mel). Abilene Christian University (ACU) has led an ongoing mobile learning research initiative and revealed compelling results, including increased student engagement, teacher and student innovation, and teamwork (go.nmc.org/acumlr). Northdale Middle School in Minnesota reported that tablets and apps have helped students with severe cognitive and development disabilities better grasp vocabulary words and gain more confidence. go.nmc.org/corap

A sampling of mobile learning applications across disciplines includes the following:

> **Mathematics.** Year four students at St Leonard's College, a primary school in Australia, are using tablets loaded with math apps and e-textbooks to access information, receive instruction, record measurements, and conduct research: go.nmc.org/stle.

> **Music.** Students at Institut International de Lancy in Switzerland use their tablets to create music in the school's first iPad Orchestra. The iPads have provided opportunities for students with little or no musical training to create their own music with classmates: go.nmc.org/iil.

> **Storytelling.** Ringwood North Primary School in Australia participated in "The Epic Citadel Challenge." Teachers and students collaborated to write a digital story based on the Epic Citadel environment, which they turned into an app that can be accessed via iOS mobile device: go.nmc.org/stor.

Mobile Learning in Practice
The following links provide examples of mobile learning in use in K-12 education settings:

BYOD Lessons
go.nmc.org/sou
At South Middle School in Kentucky, students must take an online course about Internet safety before they are able to use their own devices in class. One way that students use their mobiles is to text answers to multiple choice questions posed during a lesson, giving teachers instant insight into whether extra time is needed for a topic.

The Global Enterprise Mobile Alliance
go.nmc.org/vcxdl
Multi-media service (MMS) provider Navita launched the Global Enterprise Mobile Alliance, a coalition of seven MMS providers who are working together to make BYOD a reality for Brazilian businesses and students.

iPads in Australian Special Education
go.nmc.org/spe
The use of iPads for special education has been tested in various locations across Australia, most significantly in Victoria at Warringa Park School. Results indicate the devices were useful in facilitating individualized learning both within the classroom and out in the community. Apps led students through exercises that helped develop fine motor control, vocabulary, speech, and design skills.

iPads at ZIS International School
go.nmc.org/ZIS
Students at ZIS International School in Switzerland use iPads as video cameras, audio recorders, and multimedia notebooks to capture learning experiences for their personal blogs and digital portfolios.

Mobile Learning at Lee's Summit
go.nmc.org/leesum
Lee's Summit R-7 School District in Missouri created a web page with mobile learning resources, including apps, to promote the creative use of mobile devices for in-classroom and on-the-go learning.

New Trier's Mobile Learning Initiative
go.nmc.org/ntthsd
New Trier Township High School District in Illinois launched the Mobile Learning Initiative to evaluate the effectiveness of tablets for teaching and learning. Early reports cite improved student organization.

For Further Reading

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

17 Ways iPads Will be Used in Schools in 2013
go.nmc.org/17ways
(Roger Riddell, *Education Dive*, 12 February 2013.) *Education Dive* explores iPad pilots that are underway at various institutions, describing how the mobile devices are expected to replace textbooks in some schools and to broadcast lessons to rural areas with teacher shortages.

For Low-Income Kids, Access to Devices Could Be the Equalizer
go.nmc.org/equ
(Tina Barseghian, *MindShift*, 13 May 2013.) Access to devices is noticeably different between higher and lower income schools; 52% of teachers of upper and upper-middle income students say their students use cell phones to look up information in class, compared with 35% of teachers of the lowest income students.

Mobile Device Smack Down
go.nmc.org/sma
(Jennifer Magiera, *EdReach*, 12 April 2013.) This podcast explores why certain mobile devices are better choices than others for the classroom, how purchasing and downloading apps to multiple devices works, and describes syncing solutions and current tech requirements for Common Core assessments.

Mobile Learning: 5 Advantages and 5 Disadvantages
go.nmc.org/mobile5
(Mashii Hajim, *Edudemic*, 28 December 2012.) Positive outcomes of mobile learning include increased engagement and wider access to educational resources. The author cites cost and battery life among the potential negatives.

Mobile Learning Support for New Teachers
go.nmc.org/lisad
(Lisa Michelle Dabbs, *Edutopia*, 10 October 2012.) This article provides a framework for mobile learning for new teachers or schools considering mobile learning, such as developing responsible use policies and planning mobile activities with students.

Schools Set Boundaries for Use of Students' Digital Devices
go.nmc.org/bou
(Robin L. Flanigan, *Education Week*, 7 February 2013.) Schools in Minnesota, Georgia, and Texas have implemented successful BYOD initiatives and discuss how their infrastructures and policies work to support the students in their learning, but still provide restrictions to counter the safety and security challenges.

The portability of mobile devices, coupled with increasingly fast web and cellular connectivity, make mobiles extremely conducive to productivity and learning. The Internet itself is becoming a mobile network.

Learning Analytics
Time-to-Adoption Horizon: Two to Three Years

Learning analytics is education's approach to "big data," a science that was originally leveraged by businesses to analyze commercial activities, identify spending trends, and predict consumer behavior. The rise of the Internet drove research into big data and metrics as well as the proliferation of web tracking tools, enabling companies to build vast reserves of information they could study and leverage in their marketing campaigns. Education is embarking on a similar pursuit into data science with the aim of improving student retention and providing a high quality, personalized experience for learners. Learning analytics research uses data analysis to inform decisions made on every tier of the educational system. Whereas analysts in business use consumer data to target potential customers and personalize advertising, learning analytics leverages student data to build better pedagogies, target at-risk student populations, and assess whether programs designed to improve retention have been effective and should be sustained — outcomes for legislators and administrators that have profound impact. For educators and researchers, learning analytics has been crucial to gaining insights about student interaction with online texts and courseware. Students are beginning to experience the benefits of learning analytics as they engage with mobile and online platforms that track data to create responsive, personalized learning experiences.*

Overview

Positioned in the mid-term horizon, learning analytics is gaining visibility as converging technologies bolster mobile and online learning trends. Initially explored for marketing purposes, the science of analytics is focused on tracking user behaviors online in order to decipher prevalent patterns and make predictions about consumer spending habits. Big data are now being used to personalize every experience users have online on commercial websites, and education administrators, major IT companies, and venture capitalists are seeing clearly analytics' potential for improving the learning environment.

The essential idea behind learning analytics is to use data and analyses to adapt instruction to individual learner needs in real time, in the same way that Amazon, Netflix, and Google use metrics to tailor recommendations and advertisements to consumers. Applied analytics can help transform education from a standard one-size-fits-all delivery system into a responsive and flexible framework, catered to meet the students' academic needs and interests. Important information can be gleaned from student work in online environments and leveraged to design adaptive software — programs that make carefully calculated adjustments and suggestions to keep learners motivated as they master concepts or encounter stumbling blocks.

Learning analytics also offers insights that inform and educate every tier of the educational system. Visualizations and analytical reports have the empirical weight needed to guide administrative and governing bodies as they target areas for improvement, allocate resources, and assess the effectiveness of programs.

inBloom Inc. has had a large part in connecting learning analytics to education reform, and is gaining visibility as a major stakeholder. Started with seed funding from the Bill & Melinda Gates Foundation and the Carnegie Corporation of New York, inBloom offers data storage, content and open source tools to help districts make personalized learning real for students in the nine states it counts as its partners (go.nmc.org/inbloom). In March 2013, inBloom was given the responsibility

of maintaining a $100 million data warehouse, a collaborative project between the Bill & Melinda Gates Foundation, the Carnegie Corporation of New York, and school officials from various states. This pool of data houses the files of millions of students in the public school system; inBloom will develop portals to allow mining of those data for a variety of purposes.

In addition to funding inBloom's endeavor, the Gates Foundation has also contributed $70 million in grants to schools and companies that are developing other sorts of personalized learning tools. Venture capitalists are investing in this sector with enthusiasm; in 2012, K-12 schools attracted over $425 million worth of deals and investments, according to a report by the New Schools Venture Fund. go.nmc.org/datab

This work is not taking place without some serious concerns being expressed over the safety of students and their information, but projects like these represent a significant shift in the way policy and other leaders are looking at what can be learned from the information we capture about students and learning. Such high-profile projects will ensure that attention remains focused on both the potential and challenges of big data analytics in education.

Relevance for Teaching, Learning, or Creative Inquiry

Schools that rely on the cloud for better, more stable infrastructures are making BYOD and one-to-one a reality for a greater number of students. As a result, online learning, and subsequently, learning analytics are getting much closer to becoming a standard practice across education. Web-based software and tracking tools are giving teachers a closer look into the learning activities of their students, while districts are using data and analytics to inform their decision-making. In all of these scenarios, learning analytics make data an integral part of planning, designing and assessing learning experiences.

Analytics platforms are becoming increasingly complex and effective. GuideK12, for example, is a web-based geovisual analytics tool that was originally designed for the U.S. Census Bureau to visualize terabytes of data in government datasets of all kinds. Repurposed for education, GuideK12 software has helped districts in Louisiana, Florida, and North Dakota gain access to numerous filters, geographic visualizations, and reports to make impactful decision-making a transparent, scientific process. go.nmc.org/guide

These and other states in the U.S. are working closely with IT solution providers to establish comprehensive data systems with the intention of optimizing taxpayer spending and streamlining the administrative flow of data. The Michigan Department of Education, for example, has partnered with Intel to update their analytics system in efforts to improve students' academic performance, inform budget and planning

Learning analytics make data an integral part of planning, designing and assessing learning experiences.

committees, and help administrators track and utilize their assets. go.nmc.org/mich

Meanwhile, as more teachers incorporate web-based software and online resources into their curricula, it has become increasingly difficult to track an individual student's progress, much less an entire class, when data is coming from multiple websites. Developers are finding ways to resolve this issue by integrating information from disparate online learning platforms into a single interface, or dashboard. Among the first of its kind, AlwaysPrepped is a free online tool that connects with educational websites like Khan Academy, Engrade, and Socrative, providing teachers with a single place to view individual and class progress. go.nmc.org/prepp

Learning analytics is also being used to detect patterns in student behavior that can help educators identify learning issues early enough to craft and implement solutions. More than 50 schools in Louisiana are using data management systems from Kickboard, a company that specializes in dashboards where teachers can keep track of student behavior, attitudes, and performance on

a daily basis. The appeal of this software is that the system can be accessed in real-time, helping teachers evaluate the fluctuating progress of individuals and classes in the cultural context of the school. go.nmc.org/kick

A sampling of applications of learning analytics across disciplines includes the following:

> **Mathematics.** Developed by a group of educators, programmers, and data scientists, Mathspace is an online program that meets the demands of the NSW Syllabus and Australian National Curriculum for students age seven to ten. The platform monitors how students reason through math problems and provides personalized feedback as well as analytics reports for teachers: go.nmc.org/mathsp.

> **Reading.** Kno, an e-textbook company, launched the "Kno Me" tool, which provides students with insights into their study habits and behaviors while using e-textbooks. Students can also better pace themselves by looking at data that shows them how much time has been spent working through specific texts, and where they are in relation to their goals: go.nmc.org/kno.

> **Special Education.** Constant Therapy is a mobile platform that leverages data analytics and mobile technology to provide personalized therapy for people with cognitive, language, communication and learning disorders. With 15 years' worth of content developed by Boston University, Constant Therapy's lessons adapt to meet the needs of learners while allowing language educators to monitor their progress via an analytics dashboard: go.nmc.org/constant.

Learning Analytics in Practice

The following links provide examples of learning analytics in use in K-12 education settings:

Adventures in "Playlisting"
go.nmc.org/summ
At Summit Public Schools in New Jersey, teachers create playlists that drive their students' personalized learning experiences. Illuminate Education provides an integrated student information system that allows teachers to create online formative assessments within each Playlist to receive pre- and post-assessment data and give students immediate feedback.

Citelighter
go.nmc.org/cit
Citelighter software helps students better organize their research and streamline their writing process. It also provides analytics that pinpoint and diagnose problem areas, allowing them to improve their writing over time.

Learning Catalytics
go.nmc.org/cataly
Recently acquired by Pearson, Learning Catalytics is a cloud-based learning analytics and assessment system developed by Harvard University professors that allows teachers to ask their students open-ended critical thinking questions and receive feedback in real-time. It also enables students to be grouped together with other students sharing similar abilities. Pearson now plans to integrate a solid student response layer into their interactive education products.

Real-Time Assessment of Standards-Based Declarative and Procedural Knowledge
go.nmc.org/bclnm
Rancocas Valley Regional High School in New Jersey is piloting a learning analytics program to determine whether immediate feedback provided to students will improve their performance with respect to targeted standards and learning outcomes — regardless of other intervening factors such as gender, socioeconomic status, or learning disabilities.

Schoology Learning Analytics (video)
go.nmc.org/fla
High school Spanish teacher Matthew Day uses Schoology in his flipped classroom so he can see how many attempts students have made before they were able to achieve a high score on their homework assignments.

For Further Reading

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

Emerging Opportunities in K-12 Learning Analytics (video)
go.nmc.org/royla
(Roy Pea, MediaX Stanford, 8 January 2013.) In this video from the MediaX 2013 Conference, Roy Pea shares why data and learning analytics are needed in building today's K-12 personalized learning at scale. His talk addresses new tools and approaches for the further development of learning analytics.

Enhancing Teaching and Learning Through Educational Data Mining and Learning Analytics: An Issue Brief
go.nmc.org/enh
(Marie Bienkowski, Mingyu Feng, Barbara Means, U.S. Department of Education, Office of Educational Technology, October 2012.) This report covers data analytics and data mining in the commercial world and how similar techniques are applied in education. It also addresses the challenges and potential of such efforts for improving student outcomes.

Hope Battles Fear Over Student Data Integration
go.nmc.org/hop
(David F. Carr, *Information Week*, 26 March 2013.) Because learning analytics relies on data collection, fears of data misuse and privacy issues are a major hurdle in its implementation. This article highlights the complaints parents have raised against a particular student data integration service, which seeks to free data from proprietary tools so it can be used for personalizing education.

If You Like Learning, Could I Recommend Analytics?
go.nmc.org/elit
(Bill Jerome, *e-Literate*, 24 March 2013.) The author discusses the differences in the analytics strategy of companies such as Amazon, Netflix, and Google, as well as exploring algorithms for education analytics that schools could employ.

Learning and Knowledge Analytics (PDF)
go.nmc.org/laknow
(George Siemens and Dragan Gasevic, *Journal of Educational Technology & Society*, Vol. 15, No. 3, July 2012.) In a special edition of the Journal, seminal learning analytics experts George Siemens and Dragan Gasevic discuss the maturation of learning analytics and its impact on education.

The Upside and Dark Side of Collecting Student Data
go.nmc.org/upside
(Katrina Schwartz, *MindShift*, 11 February 2013.) The author describes how learning analytics can provide data that helps educators better tailor learning experiences to individual students, but also cautions against companies who are using data collection to track children's activities.

Open Content
Time-to-Adoption Horizon: Two to Three Years

The movement toward open content reflects a growing shift in the way scholars in many parts of the world are conceptualizing education to a view that is more about the process of learning than the information conveyed. Information is everywhere; the challenge is to make effective use of it. Open content uses Creative Commons and other forms of alternative licensing to encourage not only the sharing of information, but the sharing of pedagogies and experiences as well. Part of the appeal of open content is that it is a response to both the rising costs of traditionally published resources and the lack of educational resources in some regions. As this open, customizable content — and insights about how to teach and learn with it — is increasingly made available for free over the Internet, people are learning not only the material, but also the skills related to finding, evaluating, interpreting, and repurposing the resources. Recent data from Edcetera indicate that open educational resources make up three quarters of the content in most MOOCs; paid content, such as required textbooks, is less than 10%. These data reflect a notable transformation in the culture surrounding open content that will continue to impact how we think about content production, sharing, and learning.

Overview

Open content, as it is described here, has its roots in a number of seminal efforts, including the Open Content Project, MIT's Open Courseware Initiative (OCW), the Open Knowledge Foundation, and work by the William and Flora Hewlett Foundation, among others. Many of these projects focused on creating collections of sharable resources and on devising licenses and metadata schemata. The era of Creative Commons has established recognized alternative licensing standards, which promote and protect the work of authors and producers under the rights that materials can be shared and distributed openly. This environment has produced an expansive network of education collaborators — teachers who are creating, adapting, and sharing media — and numerous repositories brimming with rich content.

While work in universities paved the way for open content to find traction in the classroom, its recent entrance into the K-12 sector is partly rooted in the financial benefits. Open textbooks have proven to be worthy competitors to standardized textbooks, forcing manufacturers to offer digital, customizable alternatives. An added result is the surge of educational enterprises that are providing easy to use platforms for the creation of open source texts and curricula centered on open resources. Apple's iTunes U, for example, enables educators from every sector to build courses online using the iTunes U Course Manager, which offers access to over 500,000 free public resources (go.nmc.org/itunesu). Not-for-profit repositories such as Wikibooks (go.nmc.org/wikibooks) are building ever-growing platforms that feature free, open source textbooks that are easy to find.

This philosophy of open content and open education acknowledges that information is not the only useful and distributable commodity among educators. Insight and experience can also be collected and shared. Equipped with web-based tools and a better understanding of alternative licensing, educators are more confident about creating and disseminating their own educational resources. Support for these educators is offered by a number of foundations and initiatives that promote the personalization of education through customized content. The Orange Grove, a digital repository of educational open content based out of Florida, for example, has a dedicated YouTube channel with animations that help educators understand the proper

protocol for creating, remixing, and licensing their own open educational resources. go.nmc.org/orange

As open content prompts dialog among educators and administrators in K-12 schools, there is much discussion about what is required to scale open resources. Typical business models for open content developers reflect those of non-profit organizations, foundations, or other grant or donation dependent institutions, though there are other paths to sustainability. Some open-content providers have explored models that offer opportunities for sponsorship, membership fees, and customer or premium services. Seeking partnerships with textbook publishers is also proving to be a sustainable avenue for content producers.

Meanwhile, open content has achieved global recognition as an effective means of distributing high-quality, accessible educational materials to schools in both developed and developing countries. In many parts of the world, national and state governments have allotted funds to support open content initiatives in education. In Latin America, for example, the governments of Colombia and Uruguay have launched strategic initiatives that incorporate the production and management of open educational resources. Similarly, in the eastern Pacific, Indonesia and Australia have also committed to developing frameworks to deliver open content in order to meet the needs of widely dispersed populations (go. nmc.org/surv). Likewise, in the United States, the most recent National Education Technology Plan put forth by President Obama's administration promotes the development of open content to create more innovative and accessible opportunities for learners.

Relevance for Teaching, Learning, or Creative Inquiry
The use of open content promotes a set of skills that are critical in maintaining currency in any area of study — the ability to find, evaluate, and put new information to use. The same cannot be said for many textbooks, which can be cumbersome, unchanging, and particularly costly for K-12 schools. Educators are taking advantage of open resources to expand their curricula with media-rich tools and texts that can be used and adapted to specific lessons. Formerly bound by the framework

of standardized course materials, teachers now have access to a wealth of digital information that they can use to meet district expectations.

In schools, digital textbooks have been the most widely used open educational resource, as projects have been launched to address the high cost and shortages of hardbound materials. For example, founded in 2001, the

Open content has achieved global recognition as an effective means of distributing high-quality, accessible educational materials to schools in both developed and developing countries.

California Open Source Textbook Project established a precedent as a sustainable source of high-quality digital content that adheres to state mandated K-12 curriculum standards. go.nmc.org/opsctxt

A similar initiative in Utah propelled the adoption of open textbooks for K-12 throughout the state. In 2012, the Utah State Office of Education announced that it would begin developing Utah-specific open textbooks for secondary education with the intention that schools across the state would be using the first texts by 2013. Similarly, institutions in the state, such as the public charter school Open High School of Utah, are being founded with a mission to teach 21st century skills using a curriculum based on open content (go.nmc.org/ophigh). For schools that have not yet developed open texts for their students, organizations such as the CK-12 Foundation offer free resources. Their FlexBook System is an online platform that helps educators assemble, author, and distribute media-rich digital books. go.nmc.org/ck12found

While open content has been available for a long time, the topic has received increased attention in recent

years. The flipped classroom model, for instance, encourages more teachers to create videos or use media developed and shared by their colleagues for students to explore outside of the classroom. As a result, more educators are tapping into the wealth of content within open repositories as well as familiarizing themselves with the Creative Commons licensing protocol.

As more learning takes place on mobile platforms in informal settings, open content can be leveraged to design and equip the personal learning environments of lifelong learners. The Responsive Open Learning Environments (ROLE) project, a collaborative project supported by the European Commission, promotes the idea of self-regulated learning, or making students responsible for their own learning activities by showing them how to use technology and open resources. Because ROLE's framework is open source, tools and materials created by individuals can be added to a pool of resources that all institutions can benefit from. go.nmc.org/role

A sampling of applications of open content across disciplines includes the following:

> **History.** Learn NC is a program of the University of North Carolina at Chapel Hill School of Education to make resources and best practices in K-12 freely and widely available. Their digital textbook for eighth grade history contains a collection of primary sources, readings, and multimedia that can be searched and rearranged: go.nmc.org/nch.

> **Mathematics.** Arizona instructor James Sousa has been teaching math for 15 years at both the community college and K-12 levels. He has developed more than 2,600 video tutorials on topics from arithmetic to calculus, which are licensed under a Creative Commons Attribution license: go.nmc.org/sousa.

> **Science.** A partnership between Brigham Young University's David Wiley and the Hewlett Foundation sparked a project in which teachers from 18 districts and four charter schools across Utah pulled together science resources to create free digital textbooks: go.nmc.org/uta.

Open Content in Practice
The following links provide examples of open content in use in K-12 education settings:

Curriki
go.nmc.org/curriki
Curriki is a nonprofit aimed at creating a global community for sharing curriculum and best practices in K-12. Over 46,000 resources contributed by educators, partners, and parents are available through the site, organized by topic and rated by users.

Gooru
go.nmc.org/gooru
Gooru is a STEM education research, search, and curation portal that relies on crowd sourcing and collective intelligence. A team of educators is tagging curated teaching resources at the conceptual level. They identify factually correct, image-rich web content that can aid students and teachers when they are learning about a specific subject, such as velocity.

Mathematics Vision Project
go.nmc.org/matvis
The Mathematics Vision Project, in partnership with the Utah State Office of Education, provides sequenced curriculum modules for mathematics. Using a Creative Commons 3.0 license, the material can be shared and remixed with proper attribution.

MERLOT
go.nmc.org/merlot
MERLOT, a multimedia educational resource for online learning, is a California State University program that houses a collection of open learning materials from a range of disciplines, including English, physics, and world languages.

Open Textbooks in Poland
go.nmc.org/polandoer
The Office of the Polish Prime Minister implemented the biggest governmental open educational resources initiative in that nation to date, mandating open-content textbooks for grades four through six.

Share My Lesson

go.nmc.org/myless

Share My Lesson is an online community where educators can access and exchange educational resources. Registered users can search by grade, discipline, or topic, and connect with others through discussion forums.

For Further Reading

The following articles and resources are recommended for those who wish to learn more about open content.

80 Open Education Resource (OER) Tools for Publishing and Development Initiatives

go.nmc.org/80oer

(Open Education Database, 18 March 2013.) This compilation provides institutions with open resources for a range of academic activities, including publishing content, building online courses, tutoring students, and collaborating on projects.

Guide to the Use of Open Educational Resources in K-12 and Postsecondary Education (PDF)

go.nmc.org/guideopen

(Sue Collins, Peter Levy, SIIA, March 2013.) Many important questions about open educational resources are answered, including inquiries on quality, sustainability, total cost of development, and implementation.

Open Resources: Transforming the Way Knowledge Is Spread

go.nmc.org/openre

(D. D. Guttenplan, *The New York Times*, 18 March 2012.) This article examines the state of open content in education. The author sees open content as vital to extending literacy and opportunity while cutting costs for schools, families, and students worldwide.

"Opening" a New Kind of School: The Story of the Open High School of Utah

go.nmc.org/openew

(DeLaina Tonks, Sarah Weston, et al., *The International Review of Research in Distance and Open Learning*, March 2013.) The Open High School of Utah is a full-time online high school whose courses are developed and taught in

Moodle. They have committed to an OER curriculum to help reduce long-term costs and empower teachers in building and teaching high quality material.

Out of Print: Reimagining the K-12 Textbook in a Digital Age

go.nmc.org/oop

(Fletcher, G., Schaffhauser, D., & Levin, D. State Educational Technology Directors Association, 2012.) The authors of this report argue that traditional textbooks should be replaced with high-quality online resources that are up to date and easily accessible. Digital content is more flexible than printed materials because it allows teachers to benefit from a greater selection of open educational resources and provides the possibility of customized lesson plans.

Survey on Governments' Open Educational Resources Policies

go.nmc.org/surv

(Sarah Hoosen, Commonwealth of Learning and UNESCO, June 2012) In a survey of 82 countries, data was collected about the uptake and impact of OER in both K-12 and higher education environments across the world. The discussion looks at OER in Asia and the Pacific, Arab States, Europe, North America, Latin America, the Caribbean, and Africa.

3D Printing

Time-to-Adoption Horizon: Four to Five Years

Known in industrial circles as rapid prototyping, 3D printing refers to technologies that construct physical objects from three-dimensional (3D) digital content such as 3D modeling software, computer-aided design (CAD) tools, computer aided tomography (CAT), and X-ray crystallography. A 3D printer builds a tangible model or prototype from the electronic file, one layer at a time, through an extrusion-like process using plastics and other flexible materials, or an inkjet-like process to spray a bonding agent onto a very thin layer of fixable powder. The deposits created by the machine can be applied very accurately to build an object from the bottom up, layer by layer, with resolutions that, even in the least expensive machines, are more than sufficient to express a large amount of detail. The process even accommodates moving parts within the object. Using different materials and bonding agents, color can be applied, and parts can be rendered in plastic, resin, or metal. This technology is commonly used in manufacturing to build prototypes of almost any object (scaled to fit the printer, of course) that can be conveyed in three dimensions.

Overview

3D printing is already pervasive in a number of fields, including architecture, industrial design, jewelry design, and civil engineering. The earliest known examples were seen in the mid-1980s at the University of Texas at Austin, where selective laser sintering was developed, though the equipment was cumbersome and expensive. The term 3D printing itself was coined a decade later at the Massachusetts Institute of Technology, when graduate students were experimenting with unconventional substances in inkjet printers. 3D printing appeared in the very first *NMC Horizon Report*, published in 2004, and since then, it has helped the U.S. Department of Defense to inexpensively create aerospace parts, architects

create models of buildings, medical professionals develop body parts for transplants, and much more.

In the past several years, there has been a lot of experimentation in the consumer space — especially within the Maker culture, a technologically-savvy, do-it-yourself community dedicated to advancing science, engineering, and other disciplines through the exploration of 3D printing and robotics. Those involved in the many Maker communities around the world emphasize invention and prototyping. The MakerBot (go.nmc.org/maker) is a 3D desktop printer that allows users to build everything from toys to robots, to household furniture and accessories, to models of dinosaur skeletons. In 2012, MakerBot Industries released the Replicator 2, with a higher resolution compatibility and build volume. Relatively affordable at under $2,500, the MakerBot has brought 3D printing to the masses; the technology had previously only been found in specialized labs.

The resurgence of 3D printing has also been aided by online applications such as Thingiverse (go.nmc.org/thingv), a repository of digital designs for physical objects where users can download the digital design information and create that object themselves, instead of starting from scratch. The museum community in particular has capitalized on this service, creating and sharing replicas of artwork, sculptures, and fossils.

The PlayMaker school, a collaborative project between GameDesk, New Roads, and the Bill and Melinda Gates Foundation, has implemented a Maker space as part of the in-school curriculum, with lessons tied to core curriculum standards. Students design objects that can be immediately replicated and prototyped through a 3D printer to create models that demonstrate physics concepts (go.nmc.org/pla). As the technology becomes

cheaper and more prevalent in schools and afterschool programs, access will no longer be an obstacle for the widespread adoption of 3D printing.

Relevance for Teaching, Learning, or Creative Inquiry

One of the most significant aspects of 3D printing for teaching and learning is that it enables more authentic exploration of objects that may not be readily available to schools. Although 3D printing is four to five years away from widespread adoption in K-12 education, it is easy to pinpoint the practical applications that will take hold. In science and history classes, for example, students can make and interact with models of fragile objects such as fossils and artifacts. Through rapid prototyping and production tools, chemistry students can print out models of complex proteins and other molecules, similar to what can be seen in 3D Molecular Design's Model Gallery. go.nmc.org/molec

While it has become easier for teachers and students to work with these models, some of the most compelling applications of 3D printing in K-12 come from schools and programs that involve students creating something that is all their own. Sites such as 123D Catch allow users to create their own 3D images from photographs they have taken, and include an extensive how-to section. The online gallery showcases the work of users of all different ages (go.nmc.org/123dcatch). At Grand Rapids High School in Michigan, one teacher is using 123D Catch for a summer school program on digital holography. go.nmc.org/grhs3d

Higher education institutions are paving the way for 3D printing in education, and are also launching initiatives that make it more accessible to K-12 schools. A recent partnership between the Commonwealth of Virginia, University of Virginia, and the City of Charlottesville sparked the formation of the Commonwealth Engineering and Design Academy at Buford Middle School, a project-based learning school that opens in August 2013. With one 3D printer for every four students, the school aims to develop a more active curriculum. Testing is currently underway, specifically for STEM subjects. go.nmc.org/ceda

Although the MakerBot and similar models have made the technology more affordable, schools are clamoring to determine how 3D printing fits in with their curriculum. Education systems across the world are revising their standards to integrate soft skills, such as creativity, and 3D printing is becoming a more popular answer. A new curriculum standard in New Zealand, for example, will provide K-12 students with the opportunity to design and print their own chess pieces (go.nmc.org/nz3d). The exploration of the 3D printing process from design to production, as well as

> ## As the technology becomes cheaper and more prevalent in schools and afterschool programs, access will no longer be an obstacle for the widespread adoption of 3D printing.

demonstrations and participatory access, will continue to open up new possibilities for learning activities over the next several years.

A sampling of applications of 3D printing across disciplines includes the following:

> **Astronomy.** In an effort to engage inner city students in STEM related fields, Minnesota non-profit STARBASE has created an aerospace-themed curriculum where students plan a mission to Mars. A highlight of the project is the use of 3D printing technology to create a working rocket that the students launch on the final day of the program: go.nmc.org/stra.

> **Business.** In early 2013, Darwin High School in Australia initiated a project intended to expose students to micro-business concepts through product development and workflow analysis. Using 3D printers, students rapidly prototype ideas, explore product design, and learn how to market their goods: go.nmc.org/dar.

> **Computer Science.** Students at Glacier Peak High School in Washington are eligible to receive college credit for taking computer-aided design classes featuring the incorporation of 3D printers for rapid prototyping designs. The courses include modeling and design, tolerance specification, documentation drawing, and assembly modeling: go.nmc.org/cadprint.

3D Printing in Practice

The following links provide examples of 3D printing in use that have direct implications for K-12 settings.

3D Scanning and Printing at Concordia
go.nmc.org/con
At Concordia International School Shanghai, students 3D-scanned an image of the asteroid Vesta from the Dawn mission that NASA made freely available. The students created their own miniature model, allowing them to explore the asteroid, in a hands-on fashion.

Fab Lab
go.nmc.org/fab
Fab Labs began as an outreach project from MIT's Center for Bits and Atoms to research and experiment with digital fabrication. They have now materialized into centers that spread across the globe, housing technology such as 3D printers, laser cutters, and programming tools that students can use in exploratory learning environments.

STEM Academy Partnership Leverages 3D Printing
go.nmc.org/stem3d
The STEM Academy announced a partnership with 3D printing company Stratasys to integrate 3D printers into programming classes. 3D printing is a transferrable professional skill that the students will be able to cite when building their portfolios.

STEM Challenge Day at Clevedon School
go.nmc.org/cle
At Clevedon School in the UK, students took part in a STEM challenge in which they designed, 3D-printed, and tested mini "supersonic" cars that they subsequently presented to a visiting engineer from 3D Systems.

Students Use 3D Printer To Build Future
go.nmc.org/lcs3d
At the Limestone County Career Technical Center in Alabama, local high school students are using 3D printers to design and build models they can hold and explore. This gives them the ability to make revisions right away and consult with other students and educators about different engineering approaches.

For Further Reading

The following articles and resources are recommended for those who wish to learn more about 3D printing.

4D Printing: The New Frontier
go.nmc.org/4dp
(Oliver Marks, *ZDNet*, 14 March 2013.) Advances in nano biotechnology are leading to new materials that can be programmed to change their form over time. This could lead to innovations including self-repairing pants made from biological materials, vacuum-wrapped furniture that self-assembles when exposed to the atmosphere, and objects that assemble and disassemble depending on temperature.

7 Educational Uses for 3D Printing
go.nmc.org/7ed3d
(Nancy Parker, *Getting Smart*, 14 November 2012.) There is a vast array of uses for 3D printers in education, including the development of body part models for biology, 3D art, automobile parts, and historic artifacts.

10 Ways 3D Printers are Advancing Science
go.nmc.org/10ways
(Megan Treacy, *Treehugger*, 16 April 2013.) 3D printers are advancing science in many ways, from helping NASA researchers studying moon rocks to medical researchers working with 3D printed prosthetics for ears and other body parts. Specialized 3D printers are being used in labs to produce a variety of skin and other tissues that are literally "printed" onto an organic lattice.

How 3-D Printing Could Help The Blind "See" Paintings
go.nmc.org/see
(David Zax, *Fast Company*, 7 April 2013.) Harvard University students designed a system to create tactile

representations of paintings so that the visually-impaired can better experience visual art. The program uses a combination of computer-aided design software and 3D printing technology to create a protruding image, similar to a sculptural technique.

How Big Business is Stymying Makers' High-Res, Colorful Innovations
go.nmc.org/big
(Joseph Flaherty, *Wired*, 19 February 2013.) In the past year, 3D printing has been a popular topic and become a household term, due to the MakerBot releasing affordable models. However, the author suggests that the further development of the technology may be stifled because of several patents that make it impossible for start-ups and smaller entities to make improvements.

Making It Real with 3D Printing
go.nmc.org/making
(Drew Nelson, *InfoWorld*, 11 December 2012.) This article highlights the emergence of open source 3D printers, which got their start in 2007, and have now developed into less expensive, more efficient models as users share, copy, and improve upon the model designs.

Some of the most compelling applications of 3D printing in K-12 come from schools and programs that involve students creating something that is all their own.

Virtual and Remote Laboratories

Time-to-Adoption Horizon: Four to Five Years

Virtual and remote laboratories reflect a movement among education institutions to make the equipment and elements of a physical science laboratory more easily available to learners from any location, via the web. Virtual laboratories are web applications that emulate the operation of real laboratories and enable students to practice in a "safe" environment before using real, physical components. Students can typically access virtual labs 24/7, from wherever they are, and run the same experiments over and over again. Remote laboratories, on the other hand, provide a virtual interface to a real, physical laboratory. Institutions that do not have access to high-caliber lab equipment can run experiments and perform lab work online, accessing the tools from a central location. Users are able to manipulate the equipment and watch the activities unfold via a webcam on a computer or mobile device. Remote labs alleviate some financial burden for institutions as they can forgo purchasing specific equipment and use the remote tools that are at their disposal.

Overview

Virtual and remote laboratories are not new technologies, though they have become the subject of many important discussions about improving STEM education — especially in schools that cannot afford expensive technology and equipment. While virtual and remote labs are often spoken of together as they both address the challenge of increasing access to authentic science, they are different in significant ways. Remote laboratories enable users to conduct experiments and participate in activities via the Internet using remotely controlled but real laboratory equipment. Virtual laboratories are interactive online environments for performing experiments with simulated equipment. Both, however, offer the promise of authentic laboratory experiences regardless of the locale of the user.

In remote labs, the apparatuses can be monitored throughout the experiment via webcam, microphone, and other sensors. The equipment usually allows for self-cleaning when a user chooses to reset the lab. However, because there are genuine tools at work, many remote labs restrict access to one user or a group of users at a time. Virtual laboratories generally enable any number of users to conduct experiments simultaneously. In both cases, students are still accountable for data collection and analysis, though some virtual labs have built-in tools to aid the lab write-up process.

Likewise, both approaches are designed to mimic the same interactions users experience in a traditional "hands-on" laboratory, where users manipulate materials, measure liquids, press buttons, and the usual activities. Online users are able to control these actions through an interface. While the interactions are not physical, the online environment still allows users to see the consequences of their actions as they unfold, whether simulated in virtual labs or with real equipment in remote labs. If the user does not get the results they desire, there is flexibility to re-do the experiment as many times as it takes.

One of the most effective remote laboratory systems is iLab Central (go.nmc.org/ilab), featured in previous editions of the *NMC Horizon Report* for its collaborative applications and creative use of cloud computing. Developed by Northwestern University in partnership with MIT, iLab Central provides teachers and learners in traditional and online high schools, museums, and educational programs with opportunities to explore science by accessing the actual equipment that

scientists use. In testimonials, participating students cited more engagement while running experiments, along with relief that they could perform lab activities at their own pace.

Relevance for Teaching, Learning, or Creative Inquiry

Virtual and remote laboratories reflect the current trend in K-12 education toward more authentic online education. Though the technology is four to five years away from mainstream use in schools, there are already many clear benefits of implementation. Virtual and remote labs offer flexibility, as students can run experiments as many times as they like — both in and outside of school.

Because these labs are designed to allow easy repetition of experiments, there is less pressure on students to execute perfectly the first time. After learning what did not work, they can easily make adjustments to their processes and get different results. In the controlled environments of virtual and remote laboratories, students are safe, even if they make an error.

Most remote or virtual labs are currently either the result of high profile, well-funded collaborations, large grants from agencies like the National Science Foundation in the U.S., or targeted efforts by not-for-profit organizations. The American Chemical Society, for example, created a set of virtual activities for high school students. Resources such as the Molecular Workbench enable students to explore physics, chemistry, and biology through hundreds of simulations. go.nmc.org/chems

As K-12 continues to embrace online learning over the next several years, it is easy to imagine online schools that rely on virtual and remote laboratories for much of their STEM labs and activities.

A sampling of applications for virtual and remote laboratories across disciplines includes the following:

> **Chemistry.** Dr. David Yaron, Associate Professor of Chemistry at Carnegie Mellon University, developed ChemCollective, a project in the National Science Digital Library, to create flexible interactive learning

environments in which high school students can approach chemistry more like practicing scientists: go.nmc.org/chem.

> **Marine Biology.** In the Swedish town of Lysekil, high school students used virtual tools to explore

Virtual and remote labs are often spoken of together as they both address the challenge of increasing access to authentic science.

the marine environment of the Gullmar Fjord on the Swedish west coast, learning in the process how scientific knowledge is created. The students used a virtual ocean acidification laboratory to conduct studies on acidification of the marine environment: go.nmc.org/mar.

> **Mathematics.** High school students in four rural North Carolina school districts are using Geometer's Sketchpad to understand how theorems are developed. The software is accessed through North Carolina State University's virtual computing lab, a cloud-based learning environment with an interactive online community where teachers share tips on the software as well as their projects: go.nmc. org/nsf.

Virtual and Remote Laboratories in Practice

The following links provide examples of virtual and remote laboratories in use that have direct implications for K-12 settings:

Drosophila Virtual Lab
go.nmc.org/flies
In this biology-based virtual lab, students engage in experiments with digital fruit flies to determine which specific traits are passed onto offspring. In addition to the laboratory activities, the site hosts quizzes, reports, and surveys.

LabShare

go.nmc.org/labs

Labshare, National Support for Laboratory Resource Sharing, is an Australian government-funded project to create a national network of shared remotely accessible laboratories. Laboratory-based educational experiments will be available to high school students around the world.

LIGO E-Lab

go.nmc.org/ela

Mississippi high school students are required to cover wavelengths of light and properties of energy in their curriculum, and are using the same e-lab that the University of Mississippi uses to allow students to perform seismometer and interferometer experiments online.

NYU-Poly Virtual Lab

go.nmc.org/vlab

The NYU-Poly Virtual Lab is a free online lab for high school students where they can participate in and design forensics projects. Students analyze and understand how attackers take advantage of real systems and how to implement cyber security measures.

Online Virtual Lab of Electricity

go.nmc.org/buzz

The Online Virtual Lab of Electricity is an open source project that enables students to safely experiment with alternating and direct current. By manipulating a virtual connection board, users can measure voltage, intensity, and frequencies.

Virtual Physics Lab

go.nmc.org/ketvl

Kentucky Educational Television launched the Virtual Physics Lab, designed for the introductory exploration of concept development for physics. The virtual apparatus simulates real life scientific laboratory equipment.

For Further Reading

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

Can You Teach Lab Science Via Remote Labs?

go.nmc.org/teachlab

(Tony Bates, *Online Learning and Distance Education Resources*, 22 April 2013.) The Colorado Community College system has recently incorporated remote laboratories for teaching introductory physics, chemistry, and biology courses. Remote labs are different from virtual labs because they involve controlling equipment and conducting experiments in-real time.

Flipping Lab Science with Remote Labs

go.nmc.org/flipsci

(Jim Vanides, *Guide2DigitalLearning*, accessed 19 March 2013.) The author explores the role of remote science labs in the flipped classroom model. Students have more time to explore the material and run more iterations of an experiment.

It's Lab Time — Connecting Schools to Universities' Remote Laboratories (PDF)

go.nmc.org/pix

(Anne-Christin Tannhäuser, Claudio Dondi, Scienter, 2012.) Remote labs can give K-12 students the ability to access technologies used in college and university labs. The European Union has funded a project called UniSchooLabS that seeks to bring online lab resources to schools that lack in-house lab equipment by creating toolkits that teach lessons via remote telescopes and more.

A New Role for Avatars: Learning Languages

go.nmc.org/avatar

(Holly Korbey, *MindShift*, 3 May 2013.) Virtual labs are not just for science. Students from England to Brazil are using avatars in virtual language labs to enhance their language learning skills. Virtual language labs allow for students to practice in more realistic settings, such as an airport or museum, and they provide a more comfortable experience because students can select an avatar to represent them.

Using an Online Remote Laboratory for Electrical Experiments in Upper Secondary Education

go.nmc.org/usonre

(Lena Claesson and Lars Håkansson, *International Journal of Online Engineering, Vol. 8*, 2012.) While remote labs have been used in higher education for decades, the researchers of this article were interested in the application of remote labs in secondary schools in Sweden. They found that students enjoyed working in this manner because they conducted real time experiments rather than simulations.

Because these labs are designed to allow easy repetition of experiments, there is less pressure on students to execute perfectly the first time.

The NMC Horizon Project

This report is part of a longitudinal research study of emerging technologies that began in March 2002. Since that time, under the banner of the Horizon Project, the NMC and its research partners have held an ongoing series of conversations and dialogs with its advisory boards — a group that now numbers more than 800 technology professionals, campus technologists, faculty leaders from colleges and universities, museum professionals, teachers and other school professionals, and representatives of leading

The NMC Horizon Project is currently in its 11th year, dedicated to charting the landscape of emerging technologies for teaching, learning, and creative inquiry in education globally.

corporations from more than 30 countries. For more than a decade, these conversations have been mined to provide the insights on emerging technology that are published annually in the *NMC Horizon Report* series.

The NMC Horizon Project is currently in its 11th year, dedicated to charting the landscape of emerging technologies for teaching, learning, and creative inquiry in education globally. In 2008, the NMC added to the three main *NMC Horizon Reports* a new series of regional and sector-based studies, called the *NMC Technology Outlooks,* with the dual goals of understanding how technology is being absorbed using a smaller lens, and also noting the contrasts between technology use in one area compared to another.

To date, the NMC has conducted studies of technology uptake in Australia, New Zealand, the UK, Iberoamerica, Brazil, and Singapore, and has plans in place to expand that research to Central Europe and South Africa. In 2012, the *Technology Outlook* series was expanded to include sector analyses, and so far has documented technology uptake across STEM+ education and community, technical, and junior colleges.

This report, the *NMC Horizon Report: 2013 K-12 Edition*, is the fifth in its series focusing on pre-college education. The flagship *NMC Horizon Report*, focused on higher education, is translated into multiple languages every year. Over all editions, the readership of the reports is estimated at over two million worldwide, with readers in over 150 countries.

The 55 members of this year's advisory board were purposely chosen to represent a broad spectrum of the K-12 sector; key writers, thinkers, technologists, and futurists from education, business, and industry rounded out the group. They engaged in a comprehensive review and analysis of research, articles, papers, blogs, and interviews; discussed existing applications, and brainstormed new ones; and ultimately ranked the items on the list of candidate technologies for their potential relevance to teaching, learning, or creative inquiry. This work took place entirely online and may be reviewed on the project wiki at k12.wiki.nmc.org.

The effort to produce the *NMC Horizon Report: 2013 K-12 Edition* began in February 2013, and concluded when the report was released in June 2013, a period of four months. The six technologies and applications that emerged at the top of the final rankings — two per adoption horizon — are detailed in the preceding chapters.

Each of those chapters includes detailed descriptions, links to active demonstration projects, and a wide array of additional resources related to the six profiled technologies. Those profiles are the heart of the *NMC Horizon Report: 2013 K-12 Edition,* and will fuel the work of the NMC Horizon Project throughout 2013. To share your educational technology projects with the NMC to potentially be featured in a future *NMC Horizon Report*, the NMC Horizon Project Navigator database, or the NMC Horizon EdTech Weekly App, visit go.nmc.org/projects. For those wanting to know more about the processes used to generate the *NMC Horizon Report* series, many of which are ongoing and extend the work in the reports, we refer you to the report's final section on the research methodology.

The 55 members of this year's advisory board were purposely chosen to represent a broad spectrum of the K-12 sector; key writers, thinkers, technologists, and futurists from education, business, and industry rounded out the group.

Methodology

The process used to research and create the *NMC Horizon Report: 2013 K-12 Edition* is very much rooted in the methods used across all the research conducted within the NMC Horizon Project. All editions of the *NMC Horizon Report* are produced using a carefully constructed process that is informed by both primary and secondary research. Dozens of technologies, meaningful trends, and critical challenges are examined for possible inclusion in the report for each edition. Every report draws

Dozens of technologies, meaningful trends, and critical challenges are examined for possible inclusion in the report for each edition.

on the considerable expertise of an internationally renowned advisory board that first considers a broad set of important emerging technologies, challenges, and trends, and then examines each of them in progressively more detail, reducing the set until the final listing of technologies, trends, and challenges is selected.

This process takes place online, where it is captured and placed in the NMC Horizon Project wiki. The wiki is intended to be a completely transparent window onto the work of the project, and contains the entire record of the research for each of the various editions. The section of the wiki used for the *NMC Horizon Report: 2013 K-12 Edition* can be found at k12.wiki.nmc.org.

The procedure for selecting the topics in the report included a modified Delphi process now refined

over years of producing the *NMC Horizon Report* series, and began with the assembly of the advisory board. The advisory board represents a wide range of backgrounds, nationalities, and interests, yet each member brings a particularly relevant expertise. Over the decade of the NMC Horizon Project research, more than 800 internationally recognized practitioners and experts have participated on project advisory boards; in any given year, a third of advisory board members are new, ensuring a flow of fresh perspectives each year. Nominations to serve on the advisory board are encouraged; see go.nmc.org/horizon-nominate.

Once the advisory board 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. Advisory board 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. 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 throughout the process.

Following the review of the literature, the advisory board 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 advisory board:

1 **Which of the key technologies catalogued in the NMC Horizon Project Listing will be most important to teaching, learning, or creative inquiry within the next five years?**

2 **What key technologies are missing from our list? Consider these related questions:**

> **What would you list among the established technologies that some educational institutions are using today that arguably *all* institutions 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 educational institutions be actively looking for ways to apply?**

> **What are the key emerging technologies you see developing to the point that learning-focused institutions should begin to take notice during the next four to five years?**

3 **What trends do you expect to have a significant impact on the ways in which learning-focused institutions approach our core missions of teaching, research, and service?**

4 **What do you see as the key challenges related to teaching, learning, or creative inquiry that learning-focused institutions will face during the next five years?**

One of the advisory board's most important tasks is to answer these questions as systematically and broadly as possible, so as to ensure that the range of relevant topics is considered. Once this work is done, a process that moves quickly over just a few days, the advisory board moves to a unique consensus-building process based on an iterative Delphi-based methodology.

In the first step of this approach, the responses to the research questions are systematically ranked and placed into adoption horizons by each advisory board member using a multi-vote system that allows members to weight their selections. Each member is asked to also identify the timeframe during which they feel the technology would enter mainstream use — defined for the purpose of the project as about 20% of institutions adopting it within the period discussed. (This figure is based on the research of Geoffrey A. Moore and refers to the critical mass of adoptions needed for a technology to have a chance of entering broad use.) These rankings are compiled into a collective set of responses, and inevitably, the ones around which there is the most agreement are quickly apparent.

From the comprehensive list of technologies originally considered for any report, the twelve that emerge at the top of the initial ranking process — four per adoption horizon — are further researched and expanded. Once this "Short List" is identified, the group, working with both NMC staff and practitioners in the field, begins to explore the ways in which these twelve important technologies might be used for teaching, learning, and creative inquiry in K-12 education. A significant amount of time is spent researching real and potential applications for each of the areas that would be of interest to practitioners.

For every edition, when that work is done, each of these twelve "Short List" items is written up in the format of the *NMC Horizon Report*. With the benefit of the full picture of how the topic will look in the report, the "short list" is then ranked yet again, this time in reverse. The six technologies and applications that emerge are those detailed in the *NMC Horizon Report*.

For more detail on the project methodology or to review the instrumentation, the rankings, and the interim products behind the report, visit k12.wiki.nmc.org.

The NMC Horizon Project: 2013 K-12 Edition Advisory Board

Advisory board 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. 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.

The NMC Horizon Report.
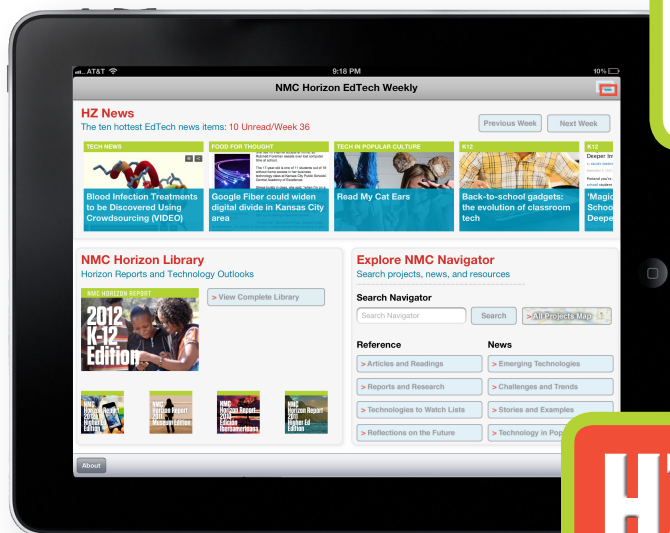# Now available weekly.

Also available for Android

Introducing the NMC Horizon EdTech Weekly App for tablets and smartphones. Get weekly updates of the hottest news in the EdTech world. Search our ever-expanding database of projects, reports, and news about innovations in teaching and learning. Download and share all *NMC Horizon Reports*. From anywhere. Find us in the iTunes Store at go.nmc.org/ios and in Google Play at go.nmc.org/android.