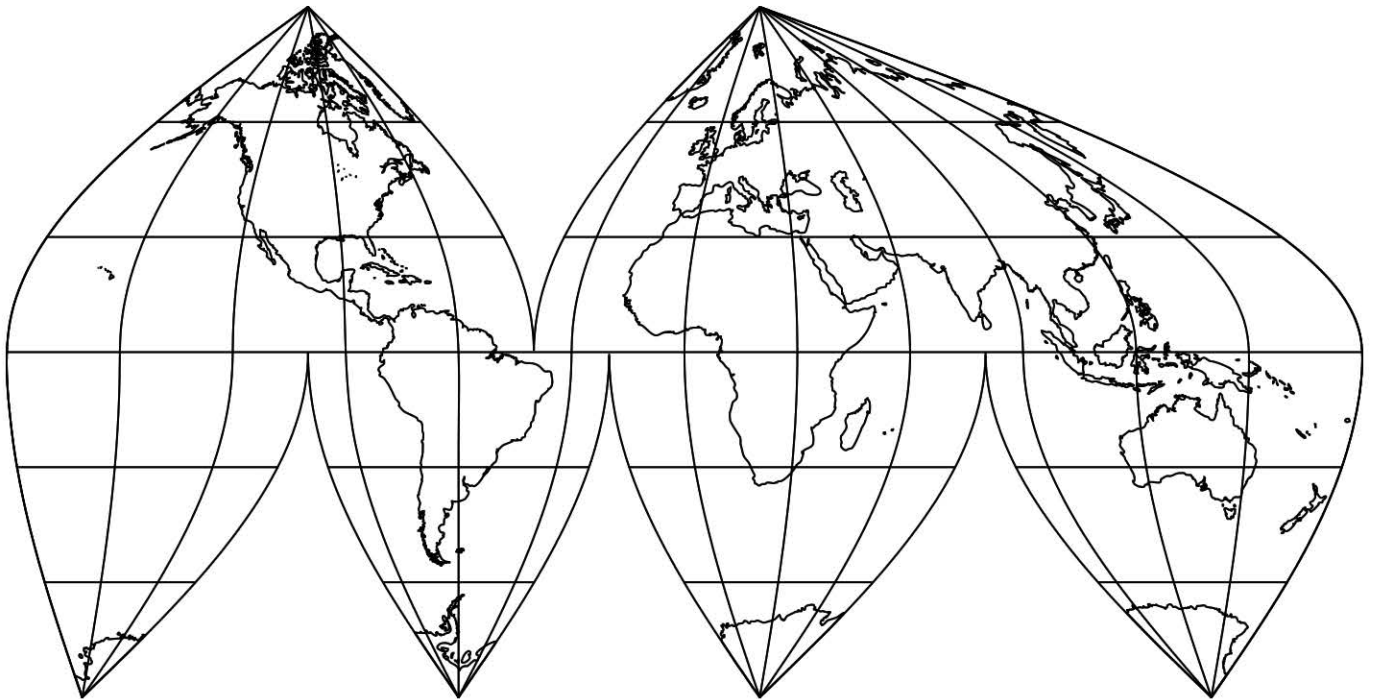**NMC** Horizon Project

Technology Outlook
STEM+ Education 2012-2017

An NMC Horizon Project Sector Analysis

The *Technology Outlook for STEM+ Education 2012-2017*
An NMC Horizon Report Sector Analysis

is a collaboration between

The NEW MEDIA CONSORTIUM

and

The Centro Superior para la Enseñanza Virtual (CSEV),
Departamento de Ingeniería Eléctrica, Electrónica y de Control
at The Universidad Nacional de Educación a Distancia (UNED), and
The Institute of Electrical and Electronics Engineers Education Society (IEEE)

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Citation

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Executive Summary

The *Technology Outlook for STEM+ Education 2012-2017* reflects a collaborative effort between the New Media Consortium (NMC), the Centro Superior para la Enseñanza Virtual (CSEV), Departamento de Ingeniería Eléctrica, Electrónica y de Control at the Universidad Nacional de Educación a Distancia (UNED), and the Institute of Electrical and Electronics Engineers Education Society (IEEE) to inform educational leaders about significant developments in technologies supporting science, technology, engineering, and mathematics education. The addition of the "+" in the acronym, as used here, incorporates communication and digital media technologies in the traditional four areas of study.

The research underpinning the report makes use of the NMC's Delphi-based process for bringing groups of experts to a consensus viewpoint, in this case around the impact of emerging technologies on teaching, learning, or research in STEM+ education over the next five years. The same process underlies the well-known *NMC Horizon Report* series, which is the most visible product of an on-going research effort begun a decade ago to systematically identify and describe emerging technologies likely to have a large impact on education around the globe.

The *Technology Outlook for STEM+ Education 2012-2017* was produced to explore emerging technologies and forecast their potential impact expressly in a STEM+ context. In the effort that ran from July through September 2012, the carefully selected group of 46 experts who contributed to this report considered hundreds of relevant articles, news, blog posts, research, and project examples as part of the preparation that ultimately pinpointed the most notable emerging technology topics, trends, and challenges for STEM+ education over the next five years.

That group of experts, known as the 2012 Horizon Project STEM+ Advisory Board, is comprised of notably knowledgeable individuals, all highly regarded in their fields. Collectively the advisory board represents a range of diverse perspectives across the STEM+ learning sector. The project has been conducted under an open data philosophy, and all the interim projects, secondary research, discussions, and ranking instrumentation can be viewed at <u>stem.wiki.nmc.org</u>. The precise research methodology employed in producing the report is detailed in a special section found at the end of this report.

The 12 "technologies to watch" presented in the body of this report reflect our experts' opinions as to which of the nearly 60 technologies considered will be most important to STEM+ education over the five years following the publication of the report. As the table below illustrates, the choices of our STEM+ experts overlap in interesting ways with those who contributed to the globally focused *NMC Horizon Report > 2012 Higher Education Edition* and the *NMC Horizon Report > 2012 K-12 Edition*. All three of these projects' advisory boards — a group of 139 acknowledged experts — agree that cloud computing and mobile apps will likely tip into mainstream use within the next year, a trend that spans all of education across much of the world. All three advisory boards saw learning analytics as an emerging science that would be making its way into schools and universities in the mid-term horizon. All also agreed that natural user interfaces are redefining how we think about and use our devices, with even the timeframe agreed upon by these three distinct groups of experts.

There are many interesting overlaps between the opinions of our STEM+ experts and the K-12 experts whose contributions were published in June 2012. Cloud computing, collaborative environments, and mobile apps were all on the near-term horizon for both reports; likewise, learning analytics and personal learning environments on the mid-term horizon; and natural user interfaces on the far-term horizon. The 93 experts from both the STEM+ and the Global Higher Education advisory boards were of like mind that the Internet of Things is four to five years away.

Comparison of "Short List" Topics Across Three NMC Horizon Research Projects

Technology Outlook for STEM+ Education 2012-2017	NMC Horizon Report 2012 Higher Education Edition	NMC Horizon Report 2012 K-12 Edition
Time-to-Adoption Horizon: One Year or Less		
Cloud Computing	Cloud Computing	Cloud Computing
Collaborative Environments	Mobile Apps	Collaborative Environments
Mobile Apps	Social Reading	Mobiles and Apps
Social Networking	Tablet Computing	Tablet Computing
Time-to-Adoption Horizon: Two to Three Years		
Augmented Reality	Adaptive Learning Environments	Digital Identity
Learning Analytics	Augmented Reality	Game-Based Learning
Massively Open Online Courses	Game-Based Learning	Learning Analytics
Personal Learning Environments	Learning Analytics	Personal Learning Environments
Time-to-Adoption Horizon: Four to Five Years		
Collective Intelligence	Digital Identity	Augmented Reality
Internet of Things	Natural User Interfaces	Natural User Interfaces
Natural User Interfaces	Haptic Interfaces	Semantic Applications
Wearable Technology	Internet of Things	Assessment of 21st Century Skills

At the same time, there were a number of distinct choices made by the STEM+ advisory board: collective intelligence, massively open online courses, social networking, and wearable technology were all considered by recent panels, but did not rise to the top of those rankings as they did here.

Wearable technology has been submitted as a potential topic for several of the most recent rounds of Horizon Project research, but this is the first time it has risen to the list of finalists, and is a brand new topic this year that should be interesting to watch as it evolves.

A growing number of key universities are looking to MOOCs as a growth medium for courses in computer science, electrical engineering, physics, and more to broader audiences. Many STEM-focused institutions are looking to open — often free — online universities to supplement the current courses at brick-and-mortar institutions.

Top Ranked Trends Across Three NMC Horizon Research Projects

Technology Outlook for STEM+ Education 2012-2017	NMC Horizon Report 2012 Higher Education Edition	NMC Horizon Report 2012 K-12 Edition
Teaching paradigms across all sectors are shifting to include online learning, hybrid learning and collaborative models.	People expect to be able to work, learn, and study whenever and wherever they want.	Paradigms in K-12 teaching are shifting to include online learning, hybrid learning and collaborative models.
Massively Open Online Courses (MOOCs) are proliferating in STEM areas.	The technologies we use are increasingly cloud-based, and our notions of IT support are decentralized.	The abundance of resources and relationships made easily accessible via the Internet is increasingly challenging us to revisit our roles as educators.
The abundance of resources and relationships made easily accessible via the Internet is increasingly challenging us to revisit our roles as educators.	The world of work is increasingly collaborative, driving changes in the way student projects are structured.	As the cost of technology drops and school districts revise and open up their access policies, it is becoming increasingly common for students to bring their own mobile devices.

Just as the nuances of the technologies and their associated adoption horizons featured in this report are specific to STEM+ education, even if there are commonalities with other reports, the

trends and challenges selected by the STEM+ advisory board distinctly reflect the current drivers and obstacles facing STEM+ education in the coming five years. For example, the advisory board agreed that the interest in massively open online courses is a trend that many world-class universities are responding to by designing open programming courses, engineering courses, and more. The experts spent a fair amount of time researching and discussing relevant trends and challenges in the context of STEM+ teaching and learning. A full discussion of trends and challenges identified by the advisory board begins on page 17; the top three from those longer lists are included in the tables in this section.

The 46 STEM+ experts saw doors opening in STEM fields to more — and more diverse — online learning opportunities, and more use of online collaboration tools. Additionally there is a growing recognition within these disciplines that the quality of the course's content should be independent of the devices used to access that content.

Horizon Project advisory boards in general have agreed that trends like these and the full list on page 17 are clear drivers of technology adoption; the STEM+ group especially saw such a linkage. At the same time, these panels of experts also agree that technology adoption can be and often is hindered by challenges both local and systemic. Many challenges impacting technology uptake are grounded in everyday realities that often make it difficult to learn about, much less adopt, new tools and approaches. Economic pressures, for example, continue to dominate conversations about the acceptance of technology in education worldwide; the challenges facing STEM+ programs also include an economic component.

Top Ranked Challenges Across Three NMC Horizon Research Projects

Technology Outlook for STEM+ Education 2012-2017	NMC Horizon Report 2012 Higher Education Edition	NMC Horizon Report 2012 K-12 Edition
Economic pressures and new models of education are bringing unprecedented competition to the traditional models of higher education.	Economic pressures and new models of education are bringing unprecedented competition to the traditional models of tertiary education.	Digital media literacy continues its rise in importance as a key skill in every discipline and profession.
Digital media literacy continues its rise in importance as a key skill in every discipline and profession.	Appropriate metrics of evaluation lag behind the emergence of new scholarly forms of authoring, publishing, and researching.	K-12 must address the increased blending of formal and informal learning.
The demand for personalized learning is not adequately supported by current technology or practices.	Digital media literacy continues its rise in importance as a key skill in every discipline and profession.	The demand for personalized learning is not adequately supported by current technology or practices.

All three advisory boards agreed that digital media literacy is continuing its rise in importance as a key skill in every discipline and profession. The challenge embedded in this long-term trend is that this change is taking place more rapidly in the workplace than in undergraduate and graduate training, and too often, in service professional development does not include skill building in communication and digital media techniques. Nonetheless, many on the STEM+ advisory board underscored the importance of these skills in science, technology, engineering, and math and called for more systemic training in techniques like animation and video that can be very effective aids to both understanding and articulating complex ideas and solutions.

Both the K-12 panel and the STEM+ panel noted that personalized learning is not adequately supported by current teaching technology or formal learning practice; at the same time, informal

learning is a space richly populated with clever apps and engaging, discovery-based learning experiences. There is a consensus that STEM+ programs are by and large not keeping up with pedagogical models that encourage students to take ownership over their own learning, develop their own learning strategies, and even manage the pace of their learning. It is critical for educators in STEM+ fields and beyond to build and participate in networks where they can share pedagogical research and best practices.

These points and comparisons provide an important context for the main body of the report that follows this summary. There, twelve key technologies are profiled, each on a single page that describes and defines a technology ranked as very important for STEM+ education over the next year, two to three years, and four to five years. Each of these pages opens with a carefully crafted definition of the highlighted technology, outlines its educational relevance, points to several real life examples of its current use on campuses or in educational practice, and ends with a short list of additional readings for those who wish to learn more. Following those discussions are sections that detail the STEM+ advisory board's ten top-most ranked trends and challenges and articulate why they are seen as highly influential factors in the adoption of any of these technologies over the coming five years.

Those key sections, and this report in general, constitute a reference and straightforward technology-planning guide for educators, researchers, administrators, policymakers, and technologists. It is our hope that this research will help to inform the choices that institutions are making about technology to improve, support, or extend teaching, learning, or research in STEM+ education. Educators and administrators worldwide look to the NMC Horizon Project and both its global and regional reports as key strategic technology planning references, and it is for that purpose that the report is presented.

Time-to-Adoption: One Year or Less

Cloud Computing

Cloud computing refers to expandable, on-demand services and tools that are served to the user via the Internet from a specialized data center. Cloud computing resources support collaboration, file storage, virtualization, and access to computing cycles, and the number of available applications that rely on cloud technologies have grown to the point that few institutions do not make some use of the cloud, whether as a matter of policy or not. Cloud computing has come to play an increasingly indispensable role in the utility of the many devices people use in everyday life. 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 extend their information and applications. As cloud computing has become ever more important, questions related to privacy, data security, and even sovereignty have led to the development of private clouds. Recently, hybrid clouds have been custom-designed to meet specialized security or other critical needs that a commodity cloud cannot.

Relevance for Teaching and Learning in STEM+ Education

- Cloud-based collaboration tools allow STEM students to engage problems as teams, to interact and brainstorm solutions easily, and to craft reports and presentations; often, the very same tools can be used to support both global and local collaboration.
- Grid computing approaches allow cloud-based servers to be organized in ways that greatly increase researchers' ability to work with very large data sets, almost on demand, increasing both the capacity and efficiency of institutional resources as needed.
- Using virtual machines in the cloud, computer science programs are able to simulate virtually any computer, from historical machines to the latest modern super computers.

Cloud Computing in Practice

- The Gaia Research for European Astronomy Training - Initial Training Network is a program where graduate students are exploring simulated data in the Gaia Universe Model Snapshot — a dataset of 1.6 billion stars stored in Amazon EC2 Cloud: go.nmc.org/pitay.
- Internet2, in partnership with 16 major technology companies, including HP and Adobe, launched NET+, a suite of specialized cloud services aimed at member universities across the United States: go.nmc.org/ynnur.
- Swinburne University is exploring how private cloud computing can be an effective vehicle for scientific workflows and data storage: go.nmc.org/swinb.

For Further Reading

Cloud Computing and Creativity: Learning on a Massively Open Online Course
go.nmc.org/clomoo
> (Rita Kop and Fiona Carroll, *European Journal of Open, Distance and E-Learning*, 20 December 2011.) This paper discusses how cloud computing can be leveraged to support collaborative learning, specifically in massively open online courses.

Cloud Computing for the Poorest Countries
go.nmc.org/qulhg
> (Quentin Hardy, *New York Times*, 29 August 2012.) Developing countries are gaining access to cloud services through battery-operated phones and servers stationed in California.

Using the Cloud to be a Better Student
go.nmc.org/vempn
> (Justin Marquis, Online Universities, 7 May 2012.) This article lists some of the many resources available via the cloud to university students and others, from free textbooks, to document creation and storage, to collaboration support.

Time-to-Adoption: One Year or Less

Collaborative Environments

Collaborative environments are online spaces — often cloud-based — where the focus is on making it easy to collaborate and work in groups, no matter where the participants may be. As the typical educator's network of contacts has grown to include colleagues who might live and work across the country, or indeed anywhere on the globe, it has become common for people who are not physically located near each other to nonetheless collaborate on projects. Joint classroom-based projects with students at other schools or in other countries are more and more commonplace as strategies to expose learners to a variety of perspectives. The essential attribute of the technologies in this set is that they make it easy for people to share interests and ideas, to easily monitor their collective progress, and to see how ideas have evolved throughout the process. These tools are compelling and widely adopted because they are not only easy to use, but they are also either very low cost or free, and often accessible with a simple web browser.

Relevance for Teaching and Learning in STEM+ Education

- Federated experiments by nature benefit from the use of collaborative environments, where researchers can easily share virtual lab books, common protocols, or critical settings.
- Simple, easy-to-use, and often free video conferencing tools, such as Skype, make it easy to involve colleagues or outside experts in discussions related to STEM topics of all kinds.
- Team-based learning situations, increasingly common in STEM-based learning, are greatly enhanced with tools that allow teams to brainstorm, jointly record observations, generate solutions, and prepare findings for dissemination.

Collaborative Environments in Practice

- The Kentucky Girls STEM Collaborative Project brings together organizations and programs that are committed to informing and motivating young women to pursue careers in STEM: go.nmc.org/ocrpm.
- Polymath is a collaborative space where mathematical quandaries are discussed openly between contributing mathematicians: go.nmc.org/osiqp.
- The Technical University of Loja in Ecuador is building an e-learning platform to analyze collaborative learning mediated by social web tools: go.nmc.org/rjpuf.
- The University Synapse project aims to create an environment that establishes connections between academia, business, and research: go.nmc.org/heuho.

For Further Reading

Collaborative Learning Environments Sourcebook
go.nmc.org/bkjvl
>   (CriticalMethods.org; accessed 3 September 2012.) This online book describes and provides links to a wide variety of collaboration resources and tools.

Creating an e-science Collaborative Environment for Neurophysiology (Video)
go.nmc.org/vcqqe
>   (Colin Ingram, University of Newcastle, *Neuroinformatics Lecture,* 23 November 2010.) Cloud services can be used to create collaborative environments for learning and sharing content in the subject of neurophysiology.

Learning Reimagined: Participatory, Peer, Global, Online
go.nmc.org/xshrq
>   (Howard Rheingold, *DMLCentral*, 22 July 2011.) This article addresses the implications of using open educational resources to influence the pedagogy behind self-organizing peer learning groups.

Time-to-Adoption: One Year or Less

Mobile Apps

There is a revolution that is taking place in software development that parallels the changes in recent years in the music, publishing, and retail industries. Mass market is giving way to niche market, and with it, the era of highly priced large suites of integrated software is giving way to a new view of what software should be. Smartphones such as the Galaxy, iPhone, and Android have redefined what we mean by mobile computing, and in the past three to four years, the small, often simple, low-cost software extensions to these devices — apps — have become a hotbed of development. New tools are free or sell for as little as 99 cents in the US, making it easier for people — even students — to develop apps. A popular app can see millions of downloads in a short time, and that potential market has spawned a flood of creativity that is instantly apparent in the extensive collections available in the app stores. These retail phenomena provide an easy, fast, totally new way to deliver software that reduces distribution and marketing costs significantly. Apple's app store opened in July 2008; Google's followed in October of that year, and since then, literally billions of apps have been sold or downloaded; simple but useful apps have found their way into almost every form of human endeavor. Mobile apps are particularly useful in education as they enable students to learn and experience new concepts wherever they are, often across multiple devices.

Relevance for Teaching and Learning in STEM+ Education

- As interactive and social features become more integrated into mobile apps, scientists can share their findings, making the app an ever-growing repository of information.
- Mobile apps provide STEM+ students with learning experiences and practice activities, from animal dissection apps to 3D views of the periodic table.
- Students are becoming more interested in STEM+ subjects as mobile app programming becomes an in-demand skill.

Mobile Apps in Practice

- BrainPOP offers an assortment of apps that engage students in STEM learning: go.nmc.org/upusu.
- Engineering students at the University of New South Wales used the "Rubrik" app to help them collect real-time data in a marketing design project competition: go.nmc.org/rubrik.
- In place of textbooks, the Duke Marine Lab developed a mobile app to teach an undergraduate biology course about marine megafauna: go.nmc.org/uffmi.
- The Spanish IEEC/UNED iPhone app contains a digital electronics module and a virtual lab that shows what happens inside of a MC68000 microprocessor when a program is executed: go.nmc.org/rvced.

For Further Reading

5 New Apps to Spur STEM Learning
go.nmc.org/oaqcf
> (Stephen Noonoo, *The Journal*, 6 February 2012.) Mobile apps that are effective for STEM learning include a human skeleton app and an interactive digital dinosaur encyclopedia.

Why Care About STEM? The Future of Mobile App Development
go.nmc.org/zkdal
> (Sam Morris, *Tablets at Work*, 16 February 2012.) This article describes the potential of mobile app development to promote STEM fields by engaging learners in project-based learning and by showing real-world applications.

Time-to-Adoption: One Year or Less

Social Networking

Social networking is about making connections and bringing people together. Conversations that take place in social networking contexts are designed to be brief, often media rich, and always inherently shareable. Communications are generally open (depending on privacy settings) and easily added to by members of the network. Today's typical students use social networking sites extensively, and in the place of email and other more traditional forms of communication. Relationships are the currency of these systems, and already we are seeing systems evolve in ways that are changing the way we search for, work with, and understand information by placing people at the center of the network. Social operating system tools, such as the analytics built into Facebook, help users understand who members of their communities know, how they know them, and how deep those relationships actually are. They can lead us to build new social connections we would otherwise have missed. As opportunities for virtual collaboration increase, trust-based networks that can interpret and evaluate the depth of a person's social connections will become increasingly indispensable.

Relevance for Teaching and Learning in STEM+ Education

- In place of traditional methods of communication, such as email, educators now share assignments and alert students to schedule changes through sites such as Facebook and Twitter. In turn, students can ask questions about assignments and receive timely responses from their teachers and classmates.
- More higher education institutions are relying on social networks as a means of recruiting students; social networks display videos and provide updates on compelling projects that are taking place in university media labs.
- Social networks provide an easy medium for informal learning that meets students on the web where they already are.

Social Networking in Practice

- Dow Chemical launched a program where their scientists are engaging in social networks to develop relationships with students at top universities: go.nmc.org/lzeav.
- Duke University and Murdoch University constructed a social map which students use to share observations about the ecosystems of Northwestern Australia: go.nmc.org/rljfg.
- Irkutsk State Technical University in Russia partnered with the Chinese University of Geosciences to build a social learning platform called the Mobile Grid Platform for STEM Subjects: go.nmc.org/bnqtf.
- Math Overflow is a community for mathematicians to post complex problems, contribute feedback, and designate the most accurate answers through voting: go.nmc.org/mdzvx.

For Further Reading

Social Media and Engineers: Live with it, OK?

go.nmc.org/pfbyw

> (Brian Fuller, *EE Times*, 22 February 2011.) This article contains examples of how engineers are blogging, tweeting, and interacting with each other online.

Social Media in the Business of Higher Education

go.nmc.org/fxhpc

> (James Michael Nolan, *Huffington Post*, 27 June 2012.) Social networking has enhanced institutions' strategies for recruitment, marketing, development, public relations, and more.

Time-to-Adoption: Two to Three Years

Augmented Reality

Augmented reality (AR), a capability that has been around for decades, has shifted from what was once seen as a gimmick to a tool with tremendous potential. The layering of information over 3D space produces a new experience of the world, sometimes referred to as "blended reality," and is fueling the broader migration of computing from the desktop to the mobile device, bringing with it new expectations regarding access to information and new opportunities for learning. While the most prevalent uses of augmented reality so far have been in the consumer sector (for marketing, social engagement, amusement, or location-based information), new uses seem to emerge almost daily, as tools for creating new applications become even easier to use. A key characteristic of augmented reality is its ability to respond to user input. This interactivity confers significant potential for learning and assessment; with it, students can construct new understanding based on interactions with virtual objects that bring underlying data to life. Dynamic processes, extensive datasets, and objects too large or too small to be manipulated can be brought into a student's personal space at a scale and in a form easy to understand and work with. A variation of augmented reality is augmented virtuality, where virtual environments are augmented by data/phenomena from the real world.

Relevance for Teaching and Learning in STEM+ Education

- Augmented reality constructs can provide contextual, *in situ* learning experiences that foster exploration of real world data in virtual surroundings and simulations. For example, Yale University constructed a virtual papermill that allowed student managers to manipulate processes and judge the ecological impacts of their decisions.
- Games that are based in the real world and augmented with networked data can give educators powerful new ways to show relationships and connections in computer science.
- Students doing outdoor fieldwork can access AR applications to overlay maps and information about their surroundings, or to enter field observations and data that is automatically geocoded as the records are created.

Augmented Reality in Practice

- At Super School University, educators and students from 34 countries are working as scientists, using the island of Santa Luzia for a collaborative augmented reality project: go.nmc.org/stem.
- Boise State University replaced their cadaver lab with an augmented reality tool that provides real-time 3D modeling of the human anatomy: go.nmc.org/latju.
- Microsoft partnered with University of Washington to develop augmented reality contact lenses that measure glucose levels of a wearer: go.nmc.org/ixjhf.
- The University of Exeter in the UK built an augmented reality mobile app that transforms the campus into a living lab, where users can view scientific data about their surroundings: go.nmc.org/llvuv.

For Further Reading

Augmented Reality for Chemists (Video)
go.nmc.org/augm

(Art Olson, *Chemical & Engineering News*, 19 September 2011.) This video demonstrates how AR is built, using a webcam that tracks the motions of a 3D model of a chemical.

Google's 'Project Glass' Augmented Reality Glasses Are Real And In Testing
go.nmc.org/glass

(Chris Velazco, *Tech Crunch*, 4 April 2012.) Google developed an AR glasses model that will allow users to take photos on command, display the location of nearby friends, and more.

Time-to-Adoption: Two to Three Years

Learning Analytics

Learning analytics refers to the interpretation of a wide range of data produced by and gathered on behalf of students to assess academic progress, predict future performance, and spot potential issues. Data are collected from explicit student actions, such as completing assignments and taking exams, and from tacit actions, including online social interactions, extracurricular activities, posts on discussion forums, and other activities that are not typically viewed as part of a student's work. The goal of learning analytics is to enable teachers and schools to tailor educational opportunities to each student's level of need and ability. Learning analytics promises to harness the power of advances in data mining, interpretation, and modeling to improve understanding of teaching and learning, and tailor education to individual students more effectively. Still in its very early stages, learning analytics is an emerging scientific practice that hopes to redefine what we know about learning by mining and investigating the vast amount of data produced by students as they engage in academic activities.

Relevance for Teaching and Learning in STEM+ Education

- As the need for more authentic assessment in STEM subjects increases, learning analytics help educators measure students' concept mastery across a multitude of formats.
- If used effectively, learning analytics can help surface early signals that indicate a student is struggling, allowing faculty and teaching staff to address issues quickly.
- Learning analytics draws pattern matching and analysis techniques from sciences like fluid dynamics and petroleum engineering.

Learning Analytics in Practice

- In a pilot project at the University of Kentucky, learning analytics was used to measure and improve collaborative writing for computer science students: go.nmc.org/xzifk.
- Learning analytics was used at the Graduate School of Medicine at the University of Wollongong to help design a new curriculum with a clinical focus: go.nmc.org/zgxnk.
- The University of Canterbury in New Zealand is using a learning analytics platform called LearnTrak to increase student retention: go.nmc.org/oipzz.
- The University of Michigan is leveraging learning management systems to monitor student learning in the field of engineering: go.nmc.org/peqjm.

For Further Reading

Data Mining and Online Learning
go.nmc.org/nyhsn
> (Jim Shimabukuro, *Educational Technology & Change Journal*, 7 August 2011.) The author helps educators incorporate learning analytics into their daily workflows.

Exploring the Khan Academy's use of Learning Data and Learning Analytics
go.nmc.org/rttpc
> (K. Walsh, *Emerging EdTech*22, April 2012.) The Khan Academy created a "Teacher Toolkit," which includes graphic reports to help teachers personalize the learning process.

Learning Analytics: The Coming Third Wave
go.nmc.org/mknvy
> (Malcolm Brown, EDUCAUSE Learning Initiative, April 2011.) Third-party learning analytics applications are beginning to make the tools more cost-effective.

Learning and Knowledge Analytics
go.nmc.org/igyjh
> (George Siemens; accessed 3 September 2012.) Renowned learning analytics expert George Siemens frequently updates this website with his insights on the topic, from keynotes to presentations, to blog posts.

Time-to-Adoption: Two to Three Years

Massively Open Online Courses (MOOCs)

Coined in 2008 by Stephen Downes and George Siemens, the term "massively open online courses," or MOOCs, refers to online courses that people can take from anywhere across the world. Such classes attract both novices and professionals, and in the best examples, lines between instructor and student roles are intentionally blurred. Early examples, such as EdX and Coursera, have attracted tens of thousands of participants who contribute to both the materials and organization of the course. The basis of each MOOC is an expansive and diverse set of content, contributed by a variety of experts, educators, and instructors in a specific field. What makes this content set especially unique is that it is by design a "remix" — the materials are not necessarily designed to go together but become associated with each other through the MOOC. A key component of the original vision is that all course materials and the course itself are both open source and free — with the door left open for a fee if a participant taking the course wishes university credit to be transcripted for the work. A second key element is that the structure of MOOCs be minimalist, so as to allow participants to design their own learning path based upon whatever specific knowledge or skill they want to gain. The point is that participants can control how, where, when, and even what they learn.

Relevance for Teaching and Learning in STEM+ Education

- MOOCs fill a large gap for many who simply want to participate in rich learning opportunities without the need to be admitted to a course of study or applying to a particular institution.
- Professionals who enroll in MOOCs to further their own learning can also contribute to the learning of others via mentor roles, or even as part of the teaching team.
- When more learners and institutions participate in MOOCs by sharing scientific research and other content, it leads to sustainability of the MOOC ecosystem over time.

Massively Open Online Courses in Practice

- The Centro Superior para la Enseñanza Virtual (CSEV) is encouraging MOOC enrollment to Latin American communities through an agreement with MIT to offer MOOCs in Spanish: go.nmc.org/gyorb.
- *Coursera,* a start-up by two Stanford University professors, is offering over 30 free online classes, including science fiction and health policy. A "calibrated peer-review" system is currently in the works: go.nmc.org/course.
- The Open University of Australia is an online university with a collection of courses and units provided by reputable universities around the continent: go.nmc.org/openu.

For Further Reading

Disruptive Innovation — in Education
go.nmc.org/disrup
> (Larry Hardesty, *MIT News Office*, 20 April 2012.) Learn how student interaction in the community forums of MITx has created an unpredictably advantageous learning experience.

What You Need to Know About MOOC's
go.nmc.org/wdnxj
> (*The Chronicle of Higher Education*, accessed 27 August 2012.) *The Chronicle* discusses the major players in the MOOC movement and brings together the varying opinions on the impact of these courses.

Time-to-Adoption: Two to Three Years

Personal Learning Environments

Personal learning environments (PLEs) are a loosely defined term used to describe tools that support self-directed and group-based learning, focus on individual learning goals and needs, with great capacity for flexibility and customization. The term has been evolving for some time, but has crystalized recently around the personal collections of tools and resources a person assembles to support their own learning — both formal and informal. The conceptual basis for PLEs has shifted significantly in the last two years, as smartphones, tablets, and apps have begun to emerge as compelling alternatives to browser-based PLEs and e-portfolios. There has been a corresponding move away from centralized, server-based solutions to distributed and portable ones. Using a growing set of free and simple tools and applications, or even a personally assembled collection of apps on a tablet, it is already easy to support one's ongoing social, professional, and learning activities with a handy collection of resources and tools that are always with you. While the concept of PLEs is still fairly fluid, it is clear that a PLE is not simply a technology but an approach or process that is individualized by design, and thus different from person to person.

Relevance for Teaching and Learning in STEM+ Education

- Abstracts, key papers, and other research materials are easy to store in the libraries of current smartphones and tablets; course readings can easily be added to these libraries.

- As students progress through their courses of study, their PLEs grow in sophistication as well as utility.

- PLEs provide a framework for STEM students to assemble collections of reference materials, specialized calculators, and tools that are easily at hand.

Personal Learning Environments in Practice

- "Innovative Technologies for an Engaging Classroom" is a pan-European project that joins policy-makers with educators to develop scalable learning environments: go.nmc.org/itec.
- Sabana University in Columbia conducted a case study on the use of personal learning environments as a platform for a master's course: go.nmc.org/luaho.
- Waukesha STEM Academy uses personalized and blended learning strategies to empower students to take ownership of their learning style and pace: go.nmc.org/socyf.

For Further Reading

27 Places to Get a Free Science Education
go.nmc.org/rsfwj
> (*Citizen Science Center*, 11 August 2012.) This is a collection of online resources for studying science topics that allow users to self-pace their studies.

Preparing Students to Learn Without Us
go.nmc.org/prepar
> (Will Richardson, ASCD *Educational Leadership,* February 2012.) As our culture increasingly emphasizes customization many education models are becoming more individually focused.

This Time It's Personal
go.nmc.org/person
> (Jennifer Demski, *The Journal*, 4 January 2012.) This article emphasizes the crucial role of changing the current classroom infrastructure to make it more student-centered in order to incorporate technology in a transformative way.

Time-to-Adoption: Four to Five Years

Collective Intelligence

Collective intelligence is a term for the knowledge embedded within societies or large groups of individuals. It can be explicit, in the form of knowledge gathered and recorded by many people. The tacit intelligence that results from the data generated by the activities of many people over time is extremely powerful. Google uses such data to continuously refine its search and ad results. Discovering and harnessing the intelligence in such data — revealed through analyses of patterns, correlations, and flows — is enabling ever more accurate predictions about people's preferences and behaviors, and helping researchers and everyday users understand and map relationships, and gauge the relative significance of ideas and events. Two new forms of information stores are being created in real time by thousands of people in the course of their daily activities, some explicitly collaborating to create collective knowledge stores, some contributing implicitly through the patterns of their choices and actions. The data in these new information stores has come to be called collective intelligence, and both forms have already proven to be compelling applications of the network. Explicit knowledge stores refine knowledge through the contributions of thousands of authors; implicit stores allow the discovery of entirely new knowledge by capturing trillions of key clicks and decisions as people use the network in the course of their everyday lives.

Relevance for Teaching and Learning in STEM+ Education

- Collective intelligence is embedded in scientific research networks. Data mining tools provide both a way to search for patterns and insights as well as to illustrate the topic.
- Professional networks provide an avenue for STEM professionals to make instant updates to research and topics, absent the inherent time constraints involved in updating a traditional paper.
- The study of tacit knowledge stores such as usage or traffic patterns, user interactions, and similar large datasets often leads to unexpected insights.

Collective Intelligence in Practice

- ChemSpider, developed by the Royal Society of Chemistry, is a free database for chemical structures, gathering research from across the web into a single repository: go.nmc.org/zuvpk.
- The Khan Academy is a vast but highly curated collection of videos that supplement school curriculum: go.nmc.org/jlwbj.
- The National Archives partnered with Wikipedia on the Wikipedians-in-Residence program, where volunteer experts publicly document the history of cultural institutions: go.nmc.org/wsgub.

For Further Reading

Crowd Computing and Human Computation Algorithms at Collective Intelligence (video)
go.nmc.org/yptvv
> (Rob Miller, 2012 Collective Intelligence Conference.) In an event sponsored by the National Science Foundation, a researcher explores the infrastructures of collective intelligence.

Interview with Pierre Lévy on Collective Intelligence Literacy
go.nmc.org/smzwz
(Pierre Lévy, *Flat Classroom*, 20 October 2011.) A media scholar discusses collective intelligence in the context of new media and digital networks, and the skills and philosophies people need to contribute to the conversation.

Time-to-Adoption: Four to Five Years

The Internet of Things

The Internet of Things has become a sort of shorthand for network-aware smart objects that connect the physical world with the world of information. A smart object has four key attributes: it is small, and thus easy to attach to almost anything; it has a unique identifier; it has a small store of data or information; and it has a way to communicate that information to an external device on demand. The Internet of Things extends that concept by using TCP/IP as the means to convey the information, thus making objects addressable (and findable) on the Internet. Objects that carry information with them have long been used for the monitoring of sensitive equipment or materials, point-of-sale purchases, passport tracking, inventory management, identification, and similar applications. Smart objects are the next generation of those technologies — they "know" about a certain kind of information, such as cost, age, temperature, color, pressure, or humidity — and can pass that information along easily and instantly upon electronic request. They are ideal for digital management of physical objects, monitoring their status, tracking them throughout their lifespan, alerting someone when they are in danger of being damaged or spoiled — or even annotating them with descriptions, instructions, warranties, tutorials, photographs, connections to other objects, and any other kind of contextual information imaginable. The Internet of Things would make access to these data as easy as it is to use the web.

Relevance for Teaching and Learning in STEM+ Education

- Attached to scientific samples, TCP/IP-enabled smart objects already are alerting scientists and researchers to conditions that may impair the quality or utility of the samples.
- Pill-shaped microcameras are used in medical diagnostics and teaching to traverse the human digestive tract and send back thousands of images to pinpoint sources of illness.
- TCP/IP enabled sensors and information stores make it possible for geology and anthropology departments to monitor or share the status and history of even the tiniest artifact in their collections of specimens from anywhere to anyone with an Internet connection.

Internet of Things in Practice

- Cosm is a platform that connects devices and apps so they can store and exchange data. Developers are using it to create their own smart products: go.nmc.org/kzhep.
- In Rio de Janeiro, scientists are deploying ground and airborne smart sensors to predict heavy rains and mudslides up to 48 hours in advance: go.nmc.org/mzytn.
- MIT's Amarino is a toolkit that allows smartphone users to control the lights in a room and detect exposure levels to potentially harmful environmental factors: go.nmc.org/uyllx.

For Further Reading

Futurist's Cheat Sheet: Internet of Things
go.nmc.org/cpfez
> (Dan Rowinski, *Read Write Web*, 31 August 2012.) The author explores a world where objects have their own IP addresses and communicate with each other via WiFi or cellular networks.

How the "Internet of Things" Is Turning Cities Into Living Organisms
go.nmc.org/cxmqs
> (Christopher Mims, *Scientific American*, 6 December 2011.) If city systems are able to react to information stored in the cloud, they can respond to new environmental conditions.

The Internet Gets Physical
go.nmc.org/yirhc
> (Steve Lohr, *The New York Times*, 17 December 2011.) Smart devices are linking humans to their environment in ways that will benefit energy conservation, health care, and more.

Time-to-Adoption: Four to Five Year

Natural User Interfaces (NUIs)

It is already common to interact with a new class of devices entirely by using natural movements and gestures. Smart phones, tablets, game consoles, and the new class of "smart TVs" are part of a growing list of other devices built with natural user interfaces that accept input in the form of taps, swipes, and other ways of touching; hand and arm motions; body movement; and increasingly, natural language. These are the first in a growing array of alternative input devices that allow computers to recognize and interpret natural physical gestures as a means of control. Natural user interfaces allow users to engage in virtual activities with movements similar to what they would use in the real world, manipulating content intuitively. The idea of being able to have a completely natural interaction with your device is not new, but neither has its full potential been realised. What makes natural user interfaces (NUIs) especially interesting is the burgeoning high fidelity of systems that understand gestures, facial expressions, and their nuances, as well as the convergence of gesture-sensing technology with voice recognition, which allows users to interact in an almost natural fashion, with gesture, expression, and voice communicating their intentions to devices.

Relevance for Teaching and Learning in STEM+ Education

- As the ability of NUIs to read subtle changes in facial expressions and user reactions improves, STEM software will be able to "sense" when a student is struggling or frustrated with material.
- Medical students increasingly rely on simulators employing natural user interfaces to practice precise manipulations, such as catheter insertions, that would be far less productive if they had to try to simulate sensitive movements with a mouse and keyboard.
- NUIs make devices seem easier to use and more accessible; interactions are far more intuitive, which promotes exploration and engagement.

Natural User Interfaces in Practice

- A mechanical engineering team at Purdue University created Handy-Potter, a natural user interface that can modify and create shapes in 3D based on hand gestures: go.nmc.org/whfhc.
- The Norrköping Visualization Center and the Center for Medical Image Science and Visualization has developed a way for detailed CT scans to be manipulated with gestures, allowing medical students and forensic scientists to refine their autopsy and dissection techniques without needing an actual cadaver: go.nmc.org/autop.
- Students working in The Human Media Lab at Queen's University created the TeleHuman, a 3D visualization of a person based on Microsoft Kinect sensor technology: go.nmc.org/aluov.

For Further Reading

The Human Voice, as Game Changer
go.nmc.org/voice
> (Natasha Singer, *The New York Times*, 31 March 2012.) This article paints a picture of how the voice-enabled future will materialize as we begin to interact in new ways with everyday objects, such as refrigerators, thermostats, alarm systems, and other devices.

Natural User Interfaces
go.nmc.org/cvtqw
> (Charles Xie, *The Advanced Educational Modeling Laboratory*, 21 August 2012.) The head of the Mixed Reality Labs project funded by the National Science Foundation explains Natural Learning Interfaces (NLI), natural user interfaces that allow users to interact with simulations on a computer.

Time-to-Adoption: Four to Five Years

Wearable Technology

Wearable technology refers to devices that can be worn by users, taking the form of an accessory such as jewelry, sunglasses, a backpack, or even actual items of clothing like shoes or a jacket. Often discreet, a person who comes into contact with someone wearing a device may not even realize that the article of clothing is a piece of technology. The benefit of wearable technology is that it can conveniently integrate tools, devices, power needs, and connectivity within a user's everyday life and movements. Google's Project Glass features one of the most talked about current examples —the device resembles a pair of glasses but with a single lens. A user can literally see information about their surroundings displayed in front of them, such as the names of friends who are in close proximity, or nearby places to access data that would be relevant to a research project. Wearable technology is still very new, but one can easily imagine accessories such as gloves that enhance the user's ability to feel or control something they are not directly touching. Wearable technology already in the market includes clothing that charges batteries via decorative solar cells, allows interactions with a user's devices via sewn in controls or touch pads, or collects data on a person's exercise regimen from sensors embedded in the heels of their shoes.

Relevance for Teaching and Learning in STEM+ Education

- Enabling technologies such as flexible screens or new forms of conducting materials or insulators are natural research pathways for students interested in embedding devices or their components into clothing.
- Smart jewelry or other accessories could alert wearers to hazardous conditions, such as exposure to carbon monoxide.
- Wearable technology provides an engaging set of design and engineering challenges that cuts across a wide range of STEM disciplines.

Wearable Technology in Practice

- Keyglove is a wireless, open-source input device a user wears over the hand to control devices, enter data, play games, and manipulate 3D objects: go.nmc.org/fylwm.
- Researchers at the University of South Carolina converted the fibers of a t-shirt into activated carbon to transform it into electrical storage capacity that can be used to keep mobile devices charged: go.nmc.org/zscll.
- The University of Illinois at Urbana-Champaign designed a flexible circuit to enhance surgical gloves and improve sensory response: go.nmc.org/hwcpj.

For Further Reading

Smart Couture: Wearable Tech Finds Its Fit
go.nmc.org/vhgnx
> (David Zax, *Fast Company*, 15 August 2011.) The latest generation of wearable technology is sleeker and more comfortable. This article provides several innovative examples.

Wearable Tech Market on the Upswing
go.nmc.org/fqpor
> (Lucas Mearian, *Computer World New Zealand,* 27 August 2012.) This article describes wearable devices that will be emerging for daily use allowing wearers to instantly access personal data, including glasses and watches that collect and transmit health data.

Wearable Technology: a Vision of the Future?
go.nmc.org/sxgxs
> (Charles Arthur, *The Guardian*, 18 July 2012.) Though tools such as smart glasses increase our connectedness to our surroundings, they raise the privacy concerns that come with wearing a device that records everything we see or do.

Top Ten Trends

The technologies featured in the NMC Horizon Project are embedded within a contemporary context that reflects the realities of the time, both in the sphere of education and in the world at large. To assure this perspective, each advisory board researches, identifies, and ranks key trends that are currently affecting the practice of teaching, learning, and research in education, and uses these as a lens for its work in predicting the uptake of emerging technologies in whatever sector is their focus.

These trends are surfaced through an extensive review of current articles, interviews, papers, and new research. Once identified, the list of trends is ranked according to how significant an impact they are likely to have on education in the next five years. The following trends have been identified as key drivers of technology adoptions in STEM+ education for the period of 2012 through 2017; they are listed here in the order they were ranked by the advisory board.

1) Teaching paradigms across all sectors are shifting to include online learning, hybrid learning, and much more teamwork and collaboration. Budget cuts have forced institutions to re-evaluate their traditional approaches and find alternatives to seat-bound learning models. What Horizon Project researchers began tracking several years ago as a challenge has morphed in this climate into an increasingly interesting trend. Students already spend much of their free time on the Internet. We are beginning to see developments in online learning that offer similar — and for particular groups of students, even better — environments than physical campuses, and include team tasks and digital skills. Hybrid models, which blend classroom and online experiences, are often seen as the best of both worlds, and thus are emerging as an ever more common norm for course design.

2) Massively Open Online Courses (MOOCs) are proliferating, especially in STEM disciplines. Led by the successful early experiments of world-class institutions (like MIT and Stanford), MOOCs have captured the imagination of senior administrators and trustees like few other educational innovations have. High profile offerings are being assembled under the banner of institutional efforts like MITx, and large-scale collaborations like Coursera and the Code Academy. As the ideas evolve, MOOCs are increasingly seen as a very intriguing alternative to credit-based instruction. The prospect of a single course achieving enrollments in the tens of thousands is bringing serious conversations on topics like micro-credit to the highest levels of institutional leadership.

3) The abundance of resources and relationships made easily accessible via the Internet is increasingly challenging us to revisit our roles as educators. Institutions must consider the unique value that each adds to a world in which information is everywhere. 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 is again at the forefront. Higher education institutions have always been seen as critical paths to educational credentialing, but challenges from competing sources are redefining what these paths can look like.

4) People expect to be able to work, learn, and study whenever and wherever they want. This trend is certainly true for most adults, and many well-paying jobs literally can be done from anywhere that has a mobile Internet connection. It is also true for many of today's school-age children, who live their lives in a state of constant connection to their peers, social groups, and family. The implications for formal learning are profound, as the flipped classroom uses the resources on the Internet to free up valuable teacher classroom time, and fundamentally changes the teacher-student relationship. When students know how to use their network connections for more than texting, learning becomes much more serendipitous, opening the door to "just-in-time" learning, and "discovered" learning.

5) New pedagogical models are emerging that encourage a wide range of technologies and tools to be imbedded seamlessly into the course design. In the traditional pattern, when a new technology emerges, there is a period of time where it is studied as an independent variable to find out its impact on learning outcomes. New pedagogies are emerging, however, in which technologies play a supporting, rather than a central role, allowing much faster assessment of the value of the tools employed. In these models, more basic ideas are central, such as 24/7 Internet access for students, use of their personal devices, and considerable flexibility in the apps or software applied to the learning goals.

6) Increasingly, students want to use their own technology for learning. As new technologies are developed at a more rapid pace and at a higher quality, there is a wide variety of different devices, gadgets, and tools from which to choose. Utilizing a specific device has become something very personal — an extension of someone's personality and learning style — for example, the iPhone vs. the Android. There is comfort in giving a presentation or performing research with tools that are more familiar and productive at the individual level. And, with handheld technology becoming mass produced and more affordable, students are more likely to have access to more advanced equipment in their personal lives than at school.

7) There is a new emphasis in the classroom on more challenge-based and active learning. Challenge-based learning and similar methods foster more active learning experiences, both inside and outside the classroom. As technologies such as tablets and smartphones now have proven applications in schools, educators are leveraging these tools, which students already use, to connect the curriculum with real life issues. The active learning approaches are decidedly more student-centered, allowing them to take control of how they engage with a subject and to brainstorm and implement solutions to pressing local and global problems. The hope is that if learners can connect course material with their own lives and their surrounding communities, then they will become more excited to learn and immerse themselves in the subject matter.

8) Educational games are increasingly being used to not only master STEM concepts, but also apply and assess them. Games have proven benefits in engaging learners of all ages and helping them better understand complex material. Taking that notion one step further, simulations and game-based scenarios enable students to apply what they have learned in a realistic environment and receive instant feedback. Game development is one of many strategies employed in STEM environments, as it is inherently multi-disciplinary, requiring programming, engineering, design, and other key skills to create a successful game.

9) Social media is changing the way people interact, present ideas and information, and judge the quality of content and contributions. Nearly 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, alumni, and even the general public routinely use social media to share news about scientific and other developments. 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.

10) Institutions are increasingly adopting tools and technologies that allow teachers and students to better collaborate. Social networks and cloud-based tools and applications are changing the ways teachers and students communicate with each other. Open resources such as wikis and Google Apps enable the free exchange of ideas and prompt insightful discussions between teachers and students. The result is more opportunities for collaboration, and what is increasingly seen as a positive change in the dynamics of teacher-student relationships.

Top Ten Challenges

Along with the trends discussed in the preceding section, the advisory board noted a number of important challenges faced by STEM+ educators. Like the trends, the ten challenges described below were drawn from a careful analysis of current events, papers, articles, and similar sources, as well as from the personal experience of the advisory board members in their roles as leaders in education and technology. The ten challenges ranked as most significant in terms of their impact on teaching, learning, or research in STEM+ education in the coming five years are listed here, in the order of importance assigned them by the advisory board.

1) Economic pressures and new models of education are bringing unprecedented competition to the traditional models of higher education. Across the board, institutions are looking for ways to control costs while still providing a high quality of service. Institutions are challenged by the need to support ever more students with fewer resources and staff. As a result, creative institutions are developing new models to serve students. As these pressures continue, other models may emerge that diverge from traditional ones. Simply capitalizing on new technology, however, is not enough; the new models must use these tools and services to engage students on a deeper level.

2) Digital media literacy continues its rise in importance as a key skill in every discipline and profession. This challenge appears at the top of the list because despite the widespread agreement on the importance of digital media literacy, training in the supporting skills and techniques is still very rare in teacher education. As classroom professionals begin to realize that they are limiting their students by not helping them to develop and use digital media literacy skills across the curriculum, the lack of formal training is being offset through professional development or informal learning, but we are far from seeing digital media literacy as a norm. This challenge is exacerbated by the fact that digital literacy is less about tools and more about thinking, and thus skills and standards based on tools and platforms have proven to be somewhat ephemeral.

3) 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. It has become clear that one-size-fits-all teaching methods are neither effective nor acceptable for today's diverse students. Technology can and should support individual choices about access to materials and expertise, amount and type of educational content, and methods of teaching.

4) Cross-institution authentication and detailed access policies are needed to allow sharing of online experiments among institutions. While teachers are more equipped than ever to produce online experiments, what they are creating is rarely scalable. Too many institutions are recreating the same types of experiments over and over. Quality standards may improve the reuse of federated designs and experiments, but institutions also need to consider standards that would allow students from collaborating institutions to access data and tools across security domains.

5) Appropriate metrics of evaluation lag behind the emergence of new scholarly forms of authoring, publishing, and researching. Traditional approaches to scholarly evaluation such as citation-based metrics, for example, are often hard to apply to research that is disseminated or conducted via social media. New forms of peer review and approval, such as reader ratings, inclusion in and mention by influential blogs, tagging, incoming links, and re-tweeting, are arising from the natural actions of the global community of educators, with increasingly relevant and interesting results. These forms of scholarly corroboration are not yet well understood by mainstream faculty and academic decision makers, creating a gap between what is possible and what is acceptable.

6) Institutional barriers present formidable challenges to moving forward in a constructive way with emerging technologies. Too often it is the educational system's own processes and practices that limit broader uptake of new technologies. Much resistance to change is simply comfort with the status quo, but in other cases, such as in promotion and tenure reviews, experimentation or innovative applications of technologies are often seen as outside the role of researcher or scientist.

7) Traditional forms of assessment do not translate well into ICT-mediated learning scenarios. As new technologies are embedded in course designs within STEM disciplines, assessment processes must evolve as well. Writing assignments can be a very effective part of an assessment strategy, for example, but when enrollments exceed a few dozen students, they become impractical. As ICT environments scale, the assessment models must as well. We must find ways to ensure students fully demonstrate and apply their knowledge.

8) As new advances in technology present new opportunities in education, questions of inequity and inequality have never been more important. Emerging technologies and tools are supposed to provide more open access to all. However, often times only those who already have access to resources, such as Internet, can use the new tools. The challenge is to ensure we make technology choices that expand opportunity, while we also work on policies and programs that can narrow the divide.

9) Online educational resources must be more mobile-friendly. As smartphones and tablets gain more traction in educational settings, there is a demand for online content to keep up, to load quickly, to be of high quality, and to be easy to use. Online educational resources must meet this demand to be relevant to today's students.

10) The growing choice that emerging technologies make possible — and how people navigate through this choice — is an on-going challenge. When there are so many options for both educators and students on which technologies to use, it is easy to lose sight of how they will impact the teaching and learning process. In online learning environments in particular, there is a plethora of available communication, collaboration, and information management platforms. Individually, each tool or application may be effective, but when used all together, they can create a complex user interface where the focus is on the technologies rather than the learning. Navigating through the potential technologies and understanding how they will interact with each other to create a simple, easy-to-use environment is a pressing issue that must be solved at the conceptual — not implementation — level.

Methodology

The process used to research and create the *Technology Outlook for STEM+ Education 2012-2017: An NMC Horizon Report Sector Analysis* is very much rooted in the methods used throughout the NMC Horizon Project. All publications of the NMC's Horizon Project 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 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.

Much of the process takes place online, where it is captured and placed in the NMC Horizon Project wiki. This wiki, which has grown into a resource of hundreds of pages, 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 *Technology Outlook for STEM+ Education 2012-2017* can be found at stem.wiki.nmc.org.

The procedure for selecting the topics that will be in the report includes a modified Delphi process now refined over years of producing the *NMC Horizon Report* series, and it begins with the assembly of the advisory board. The board as a whole is intended to represent a wide range of backgrounds, nationalities, and interests, yet each member brings a particularly relevant expertise. To date, hundreds of internationally recognized practitioners and experts have participated in the NMC Horizon Project Advisory Boards; in any given year, a third of advisory board members are new, ensuring a flow of fresh perspectives each year.

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 is the potential relevance of the topic to teaching, learning, research, or information management. A carefully selected set of RSS feeds from dozens 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 are 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 Horizon Listing will be most important to teaching, learning, or research in STEM+ education within the next five years?

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

    a. What would you list among the established technologies that some STEM+ institutions and programs are using today that arguably ALL institutions and programs should be using broadly to support or enhance teaching, learning, or research?

    b. What technologies that have a solid user base in consumer, entertainment, or other industries should STEM+ institutions and programs be actively looking for ways to apply?

    c. What are the key emerging technologies you see developing to the point that STEM+ institutions and programs 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 STEM+ institutions and programs approach our core missions of teaching, learning, and research?

4. What do you see as the key challenges related to teaching, learning, and research that STEM+ institutions and programs 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.

For additional detail on the project methodology or to review the instrumentation, the ranking, and the interim products behind the report, please visit the project wiki at stem.wiki.nmc.org.

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