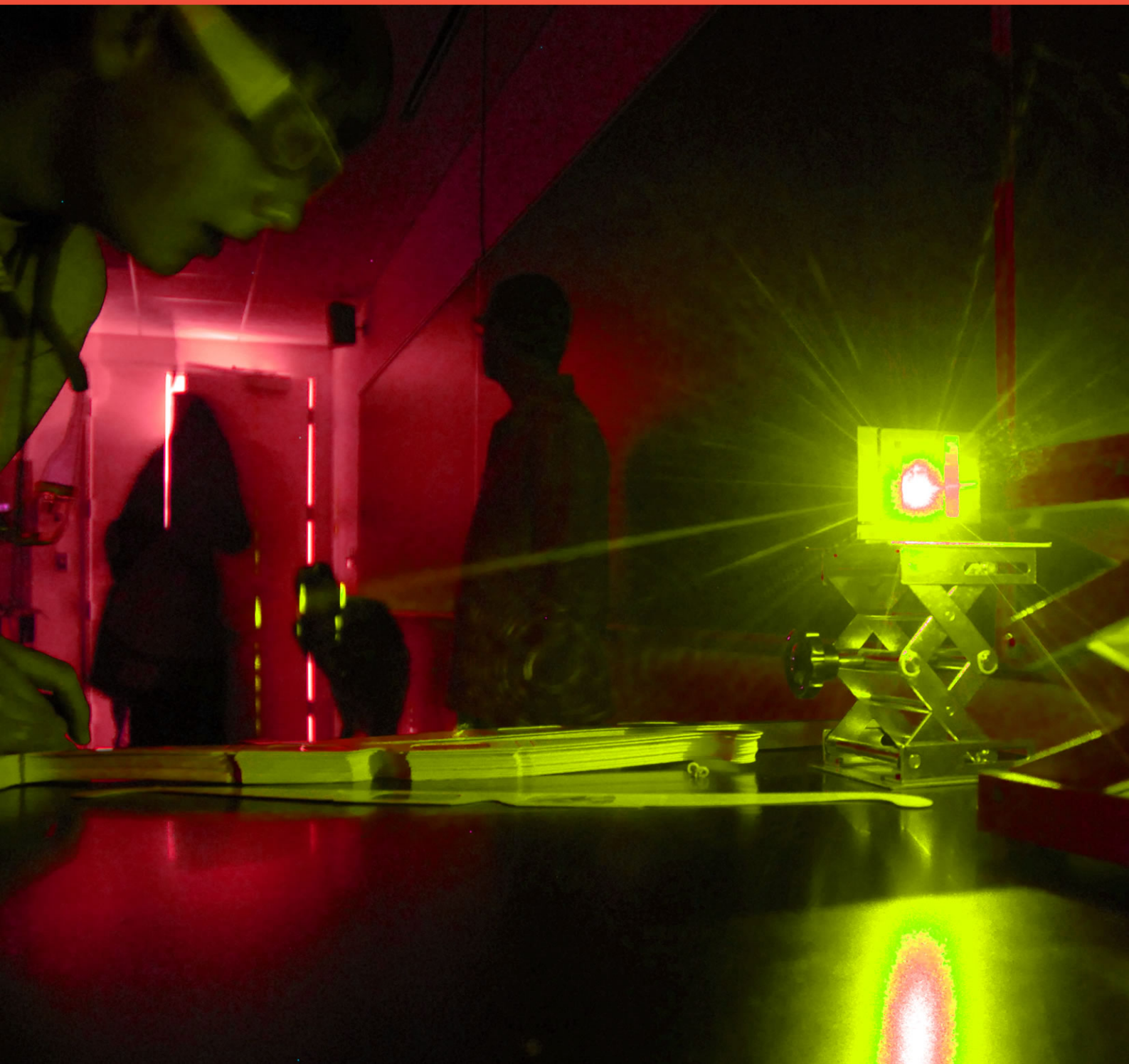# Technology Outlook

STEM+ Education 2013-2018

An NMC Horizon Project Sector Analysis

Technology Outlook for STEM+ Education 2013-2018

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The *Technology Outlook for STEM+ Education 2013-2018*
An NMC Horizon Project 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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Cover Photo: Students participating in the annual STEM program at the U.S. Naval Academy participate in
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Executive Summary

The *Technology Outlook for STEM+ Education 2013-2018: An NMC Horizon Project Sector Analysis* reflects a collaborative research effort between the New Media Consortium (NMC), the Centro Superior para la Enseñanza Virtual (CSEV), the 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 education leaders about significant developments in technologies supporting science, technology, engineering, and mathematics education. The addition of the "+" in the acronym incorporates the applications of communication and digital media technologies into the traditional four areas of study.

All of 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 STEM+ education over the next five years. The same process underlies the *NMC Horizon Report* series, the most visible product of an ongoing research effort begun in 2002 to systematically identify and describe emerging technologies likely to have a large impact on education around the globe.

The *Technology Outlook for STEM+ Education 2013-2018* was produced to explore emerging technologies and forecast their potential impact expressly in a STEM+ context. In the effort that ran from August through September 2013, the carefully selected group of 39 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.

Collectively the 2013 Horizon.STEM 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 stem.wiki.nmc.org. The precise research methodology employed in the work is detailed in a special section found at the end of this report.

Table 1: Comparison of "Final 12" Topics Across Three NMC Horizon Research Projects

NMC Horizon Report 2013 Higher Education Edition	Technology Outlook for STEM+ Education 2013-2018	Technology Outlook for STEM+ Education 2012-2017
Time-to-Adoption Horizon: One Year or Less		
Flipped Classroom	Learning Analytics	Cloud Computing
Massive Open Online Courses	Mobile Learning	Collaborative Environments
Mobile Apps	Online Learning	Mobile Apps
Tablet Computing	Virtual and Remote Laboratories	Social Networking
Time-to-Adoption Horizon: Two to Three Years		
Augmented Reality	3D Printing	Augmented Reality
Games and Gamification	Games and Gamification	Learning Analytics
The Internet of Things	Immersive Learning Environments	Massive Open Online Courses
Learning Analytics	Wearable Technology	Personal Learning Environments
Time-to-Adoption Horizon: Four to Five Years		
3D Printing	Flexible Displays	Collective Intelligence
Flexible Displays	The Internet of Things	The Internet of Things
Next-Generation Batteries	Machine Learning	Natural User Interfaces
Wearable Technology	Virtual Assistants	Wearable Technology

The 12 "technologies to watch" presented in the body of this report reflect our experts' opinions as to which of the more than 40 technologies considered will be most important to STEM+ education over the five years following the publication of the report. As Table 1 above illustrates, the choices

of our experts overlap in interesting ways with those who contributed to the *Technology Outlook for STEM+ Education 2012-2017* and the *NMC Horizon Report > 2013 Higher Education Edition,* which looked at technology uptake from a global perspective.

All three of these projects' advisory boards — a group of 136 acknowledged experts — strongly agree that mobile learning, in some form, will likely tip into mainstream use within the next year — a trend that spans all sectors of education across much of the world. However, that is where the consensus between all three stops, though there are many overlapping topics between the 2013 STEM+ report and the global report. This is most likely the case because the previous STEM+ report was produced in 2012, and in the past year, topics such as massive open online courses and learning analytics have since accelerated to the near-term horizon. Neither cloud computing nor social networking made this year's report as the advisory board feels both technologies have already crossed the bridge to widespread use in the STEM+ sector — as predicted by the 2012 group.

Both the global Higher Ed and the 2013 Horizon.STEM groups view online learning, in some form, positioned for imminent adoption in the coming year, mostly based on the rise of massive open online courses. The STEM+ field is largely driving the proliferation of online learning, with computer science and other STEM-related courses dominating catalog listings across several of the top online learning providers. Both advisory boards perceive games and gamification as two to three years away from widespread adoption. Game-play is increasingly noted for its use in helping students grasp complex STEM+ subject matter. There was also agreement about the placement of flexible displays on the far-term horizon; much of the work being done with such devices across education institutions is experimental, with companies in the consumer sector leading advancements in the field.

Table 2: Top-Ranked Trends Across Three NMC Horizon Research Projects

NMC Horizon Report 2013 Higher Education Edition	Technology Outlook for STEM+ Education 2013-2018	Technology Outlook for STEM+ Education 2012-2017
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.	Education paradigms are shifting to include online learning, hybrid learning, and collaborative models.	Teaching paradigms across all sectors are shifting to include online learning, hybrid learning, and much more teamwork and collaboration.
Massive open online courses are being widely explored as alternatives and supplements to traditional university courses.	Citizen science projects increasingly provide formal students and lifelong learners the opportunity to participate and learn in real STEM projects.	Massive open online courses are proliferating, especially in STEM disciplines.
The workforce demands skills from college graduates that are more often acquired from informal learning experiences than in universities.	As the abundance of resources and relationships made easily accessible via the Internet grows, we are ever more challenged 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 2012 Horizon.STEM and the 2013 Higher Ed experts vision of learning analytics in the mid-term horizon has materialized, and now, for the first time, we are seeing this topic placed in the near-term by the 2013 Horizon.STEM Advisory Board. This represents a real shift in focus, as more schools and universities begin to implement learning analytics strategies. Similarly, the 2013

Horizon.STEM panel placed wearable technology into the mid-term for the first time, perhaps because so much work is taking place in this arena within design and engineering departments at universities, research centers, and science centers.

A number of unique choices distinguished the viewpoints expressed by the 2013 Horizon.STEM Advisory Board from their counterparts: virtual and remote laboratories, immersive learning environments, machine learning, and virtual assistants were seen as likely developments for STEM+ education over the next five years. As online learning gains more traction, STEM+ courses are leveraging virtual and remote labs to enable students to conduct experiments as frequently as they like — anytime and from anywhere they have Internet access. This takes the pressure off of institutions to purchase and maintain expensive, high quality lab equipment.

Immersive learning environments add another dimension to the convenience of online learning by facilitating simulations so that STEM students can learn and practice new skills in the safety of a virtual environment. This is particularly helpful for medical students who are practicing performing surgery and other high-stakes procedures. Meanwhile, both machine learning and virtual assistants are being employed to interpret patterns and human gestures to support deeper learning and present users with quick and accurate data.

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. Likewise, the key trends (Table 2 and pages 17-18) and significant challenges (Table 3 and pages 19-20) selected by the 2013 Horizon.STEM Advisory Board distinctly reflect what the experts see as the current drivers and obstacles facing STEM+ education over the coming five years.

Table 3: Top-Ranked Challenges Across Three NMC Horizon Research Projects

NMC Horizon Report 2013 Higher Education Edition	Technology Outlook for STEM+ Education 2013-2018	Technology Outlook for STEM+ Education 2012-2017
Faculty training still does not acknowledge the fact that 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.	Economic pressures and new models of education are bringing unprecedented competition to the traditional models of higher education.
The emergence of new scholarly forms of authoring, publishing, and researching outpace sufficient and scalable modes of assessment.	Appropriate metrics of evaluation lag the emergence of new scholarly forms of authoring, publishing, and researching.	Faculty training still does not acknowledge the fact that digital media literacy continues its rise in importance as a key skill in every discipline and profession.
Too often it is education's own processes and practices that limit broader uptake of new technologies.	Most academics are not using new and compelling technologies for learning and teaching, nor for organizing their own research.	The demand for personalized learning is not adequately supported by current technology or practices.

The experts spent a fair amount of time researching and discussing relevant trends and challenges in the context of teaching, learning, and research in STEM+ programs. Horizon Project advisory boards in general have agreed that trends like these are clear drivers of technology adoption; the 2013 Horizon.STEM group especially saw such a linkage. At the same time, these panels of experts also agree that technology adoption is often hindered by both local and systemic challenges. 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.

The 2012 and 2013 Horizon.STEM Advisory Boards both agreed that the rapidly growing number of resources that are at students' fingertips through the Internet is changing the role of the STEM educator. It is no longer as acceptable for instructors to act solely as lecturers, dispensing information at the front and center of a classroom; instead there is a shift towards educators becoming learning designers and guides who help students navigate the abundance of content that is at their disposal.

The 2013 Horizon.STEM panel also emphasized two trends that were not at the top of the global Higher Ed group's list. First, the most highly ranked trend deals with the transitioning of education paradigms to encompass more online, hybrid, and collaborative learning, models. This trend is further underscored by the placement of online learning as a technology topic on the near-term horizon. Second, an entirely new trend also emerged from this group; increased participation in citizen science projects has enabled the public to play a more active role in the collection and analyses of scientific research. This method of crowdsourcing authentic data is being applied to more STEM+ education programs to provide students with more real world experience.

At the top of the list of challenges for STEM+ education is the act of measuring alternative forms of scholarly authoring as science journals are no longer the only mediums for published work. The 2013 Horizon.STEM Advisory Board also believes that academics in STEM+ fields are not making sufficient use of innovative technologies for their own work. The challenge that was ranked third highest by the 2012 Horizon.STEM group was re-surfaced and emphasized as the most critical issue by the 2013 Horizon.STEM group; while many educators have called for more personalized learning across education sectors, the panels feel that current technology does not yet support this customization.

These points and comparisons provide an important context for the main body of the report that follows this summary. There, 12 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 page opens with a carefully crafted definition of the highlighted technology, outlines its educational relevance, points to several real life examples of its current use, and ends with a short list of additional readings for those who wish to learn more. Following those discussions are sections that detail the advisory board's top-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, and research across 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 *Technology for STEM+ Education 2013-2018* is presented.

Time-to-Adoption: One Year or Less

Learning Analytics

Learning analytics is an educational application of "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.

Relevance for Teaching and Learning in STEM+ Education

- As the need for more authentic assessment in STEM subjects increases, learning analytics helps 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

- Georgia State University has boosted its graduation rate by implementing a supplemental instruction program that uses a web-based tracking system to alert advisors when a student makes a choice that could impact their degree completion: go.nmc.org/geor.
- Gooru is a learning search engine that allows educators to create playlists for students based on data collected from their interactions with educational media: go.nmc.org/goor.
- Supported by the Bill and Melinda Gates Foundation, PAR is a collaborative data-mining project between 16 universities and colleges: go.nmc.org/parf.

For Further Reading

If You Like Learning, Could I Recommend Analytics?
go.nmc.org/elit
> (Bill Jerome, e-Literate, 24 March 2013.) The author explains that the difference between easy learning analytics and good learning analytics is based on understanding the inputs and the outcomes.

STEMscopes: Contextualizing Learning Analytics in a K-12 Science Curriculum [VIDEO]
go.nmc.org/stsco
> (Carlos Monroy et al., LAK '13, 12 April 2013.) At the International Conference on Learning Analytics and Knowledge, researchers from Rice University presented a scalable approach for integrating learning analytics into an online science curriculum, which incorporates the methodology, architecture to curate data, and visualizations of real student and teacher data.

Time-to-Adoption: One Year or Less

Mobile Learning

We are in the midst of a complete shift in the devices we use. As smartphones and tablets become more and more capable and user interfaces more and more natural, old methods of computing seem place-bound and much less intuitive. People increasingly expect to be connected to the Internet and the rich tapestry of knowledge it contains wherever they go, and the majority of them use a mobile device to do so. According to the 2013 "ICT Facts and Figures" report from the ITU Telecommunication Development Bureau, the mobile market consists of over 6.8 billion subscribers, with a majority living in developing countries. The unprecedented evolution of these devices and the apps that run on them has opened the door to myriad uses for education. Learning institutions all over the world are adopting apps into their curricula and modifying websites, educational materials, resources, and tools so they are optimized for mobile devices. The significance for teaching and learning is that these devices have the potential to facilitate almost any educational experience, allowing learners organize virtual video meetings with peers all over the world, use specialized software and tools, and collaborate on shared documents or projects in the cloud, among many other things. Although there are still likely many uses that have not been realized yet, over the past several years mobile learning has moved quickly from concept to reality.

Relevance for Teaching and Learning in STEM+ Education

- As interactive and social features become more integrated into mobile devices, 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 can leverage the cameras, microphones, and other tools inherent in mobiles to do field work, create rich media, collect and analyze data for experiments, and more.

Mobile Learning in Practice

- Instituto Tecnológico y de Estudios Superiores de Monterrey developed Mobile Intelligent Laboratory, an app that allows users to be part of a physics experiment: go.nmc.org/mil.
- Freshmen at Jackson State University are each provided with an iPad to use as a graphing calculator, access math reference formulas and periodic tables, and more: go.nmc.org/yum.
- The University of Exeter in the UK built an augmented reality app that transforms the campus into a living lab so users can view scientific data about their surroundings: go.nmc.org/livlab.
- Thammasat University in Thailand built an IT infrastructure to support BYOD so students and staff can access content from their personal devices via wireless network: go.nmc.org/tha.

For Further Reading

The ABCs of BYOD on Campus
go.nmc.org/abc
> (Melissa Delaney, *EdTech Magazine*, 12 August 2013.) The process of building a mobile learning infrastructure, including network and device-agnostic accessibilities, is discussed.

Professional Development for Mobile Learning Improves Student Engagement & Interest in STEM Subjects
go.nmc.org/deve
> (Leila Meyer, *THE Journal*, 27 June 2013.) Findings from the Verizon Innovative Learning Schools program show that mobile learning professional development for teachers has positive effects on student engagement and interest in STEM subjects.

Time-to-Adoption: One Year or Less

Online Learning

Online learning is not new; the category encompasses any learning that takes place through web-based platforms, whether formal or informal. The learning can be structured as in traditional courses or entirely self-paced. What has made the topic new is the recent and unprecedented focus on learning via the Internet that has been fueled by massive open online courses (MOOCs). Online learning has "come of age;" quality concerns, while still important, are no longer the center of the conversation. The design of online learning is (more and more) specifically intended to encompass the latest research, the most promising developments, and new emerging business models in the online learning environment. At many institutions, online learning is an area newly ripe for experimentation — some would argue it is undergoing a sea change, with every dimension of the process open for reconceptualization. On campuses around the globe, virtually every aspect of how students connect with institutions and each other to learn online is being reworked, rethought, and redone. Universities, schools, and vendors everywhere are actively exploring solutions to assessment and learning at scale that are completely fresh and new.

Relevance for Teaching and Learning in STEM+ Education

- As new pedagogies emphasize personalized STEM+ learning, there is a growing demand for learner-centered online opportunities. Online learning environments, when designed effectively, have the potential to scale globally.

- Online learning environments can make creative use of several educational technologies and emerging instructional approaches, including blended learning, video lectures, and badges.

- The renewed focus on online learning has opened the door to new perspectives on old challenges, such as assessment, learning support, and how to ensure quality at scale.

Online Learning in Practice

- Brown University launched a free online engineering course to teach high school students about the merits and challenges of the field: go.nmc.org/bro.

- Florence-Darlington Technical College is creating a prototype online physics course to teach nuclear energy, virtually connecting students with nuclear professionals: go.nmc.org/nuc.

- The University of Maryland University College offers academic credit for students' completion of massive open online courses in seven STEM subjects: go.nmc.org/mary.

- The University of Melbourne became the first Australian university to join Coursera; epigenetics is one of the first courses planned for the launch: go.nmc.org/auscou.

For Further Reading

Massive Open Online Courses Help Make STEM Education More Accessible, But Do They Work for All Students?
go.nmc.org/aaas
> (Ginger Pinholster, AAAS, 22 May 2013.) Many different STEM higher education models have emerged with the aim of democratizing education, including self-directed MOOCs, and "flipped" classes in which students solve real world problems.

Rethink Higher Education to Exploit Digital Platforms
go.nmc.org/reth
> (David Roberts, *Times Higher Education*, 15 August 2013.) The authors describe a hypothetical "Cloud U," where students define their own educational paths, choosing from a variety of different styles of online courses that allow them to co-create lessons.

Time-to-Adoption: One Year or Less

Virtual and Remote Laboratories

Virtual and remote laboratories reflect a movement among education institutions to make the equipment and elements of a physical science laboratory 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 physical components. Students can typically access virtual labs 24/7, from wherever they are, and run the same experiments over and over again. Some emerging virtual lab platforms also incorporate reporting templates that capture the results of experiments so that students and teachers can easily review the outcomes. 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. This provides students with a realistic view of system behavior and allows them access to professional laboratory tools, whenever they need. Additionally, remote labs may alleviate some financial burden on institutions if they are able to forgo purchasing specific equipment and instead use the remote tools.

Relevance for Teaching and Learning in STEM+ Education

- Because virtual laboratories do not involve real equipment or chemicals, students can feel comfortable making mistakes and running experiments as often as they like. In addition, virtual labs can theoretically support very large numbers of students.

- Educators can play back videos of the experiments students have run online, pinpoint areas of improvement, and acknowledge students who have excelled.

- Virtual and remote labs increase access to science tools, allowing learners from all over the world to use them online; laboratory work is no longer limited to physical campuses.

Virtual and Remote Laboratories in Practice

- In the Drosophila Virtual Lab, students engage in experiments with digital fruit flies to determine which specific traits are passed on to offspring: go.nmc.org/flies.

- The Open Science Laboratory, an initiative of the Open University and the Wolfson Foundation, features investigations based on on-screen instruments, remote access experiments, and virtual scenarios using real data: go.nmc.org/opensci.

- Two researchers from Obafemi Awolowo University in Nigeria developed a Remote Operational Amplifier iLab using an Android mobile platform: go.nmc.org/ampl (PDF).

For Further Reading

A Remote Radioactivity Experiment
go.nmc.org/remnw
> (Kemi Jona and Mark Vondracek, *The Physics Teacher Online*, 2013.) A remote radioactivity lab at the University of Queensland in Australia can be accessed and managed by underserved high schools worldwide thanks to the Internet and the iLab Network.

Use of an Authentic, Industrially Situated Virtual Laboratory Project to Address Engineering Design and Scientific Inquiry in High Schools
go.nmc.org/cvlp
> (Debra M. Gilbuena et al., *Advances in Engineering Education*, Summer 2012.) Researchers from Oregon State University describe the implementation of project-based learning, based on a virtual laboratory that simulates a manufacturing process in the integrated circuits industry.

Time-to-Adoption: Two to Three Years

3D Printing

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 objects can be rendered in plastic, resin, metal, or even biological materials, such as tissue. The technology is commonly used in design and engineering labs to build prototypes of almost any object that can be rendered in three dimensions.

Relevance for Teaching and Learning in STEM+ Education

- 3D printing allows for more authentic exploration of objects that may not be readily available to education institutions, including animal anatomies and toxic materials.

- The exploration of 3D printing, from design to production, as well as demonstrations and participatory access, can open up new possibilities for learning activities.

- Typically, students are not allowed to handle fragile objects like fossils and artifacts; 3D printing shows promise as a rapid prototyping and production tool, providing users with the ability to touch, hold, and even take home an accurate model.

3D Printing in Practice

- At Konrad Lorenz University in Colombia, engineering students use 3D printers to design, prototype, and test utilitarian products: go.nmc.org/konrad.

- Engineers at the University of California, Los Angeles 3D printed a nano-tech portable smartphone attachment that can replace expensive microscopes and lab equipment to detect extremely small viruses and bacteria: go.nmc.org/micr.

- The University of Delaware's Department of Mechanical Engineering opened a design studio with a 3D printer, materials repository, machine shop, and a collaboration laboratory so students can take design ideas from concept to prototype: go.nmc.org/ude.

For Further Reading

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 objects that assemble and disassemble depending on temperature.

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 how to 3D print objects from moon rock to medical advances with 3D printed prosthetics, ears and even skin.

Time-to-Adoption: Two to Three Years

Games and Gamification

The games culture has grown to include a substantial proportion of the world's population, with the age of the average gamer increasing with each passing year. A 2013 report by the Entertainment Software Association showed that the average age of game players in the U.S. is 30 years. As tablets and smartphones have proliferated, desktop and laptop computers, television sets, and gaming consoles are no longer the only way to connect with other players online, making game-play a portable activity that can happen in a diverse array of settings. Gameplay has long moved on from solely being recreational and has found considerable traction in the worlds of commerce, productivity, and education as a useful training and motivation tool. While a growing number of educational institutions and programs are experimenting with game-play, there has also been increased attention surrounding gamification — the integration of gaming elements, mechanics, and frameworks into non-game situations and scenarios. Businesses have embraced gamification as a way to design incentive programs that engage employees through rewards, leader boards, and badges, often with a mobile component. Although more nascent than in military or industry settings, the gamification of education is gaining support among educators who recognize that it is well established that effectively designed games can stimulate large gains in productivity and creativity among learners.

Relevance for Teaching and Learning in STEM+ Education

- Discovery-based and goal-oriented learning are often inherent in educational games, fostering opportunities for collaboration and the development of teambuilding skills.
- Educational games can be used to teach cross-curricular concepts that touch on many complex scientific subjects in a more engaging way than traditional methods.
- Simulations and role-playing games allow students to re-enact difficult situations to try new responses or pose creative solutions, which is particularly helpful for medical students who are training in surgery and other high-stakes procedures.

Games and Gamification in Practice

- At the University at Albany School of Education, researchers have embarked on SUNY Games II, a project where teachers and students across disciplines explore how video game development can enrich understanding of STEM subjects in K-12 learning: go.nmc.org/gasu.
- BrainPOP's GameUp titles — largely science- and math-themed — cultivate systems thinking skills by enabling young learners to play with models of real world objects that they otherwise would not be able to: go.nmc.org/gameup.
- The Finnish-US Network, a collaboration between universities in Finland and Northern Illinois University, is conducting a study on game-based STEM learning in K-16: go.nmc.org/fins.

For Further Reading

Building STEM Skills by Learning Game Design
go.nmc.org/gdtk
> (Alex Chisholm, *Getting Smart*, 23 May 2013.) The Executive Director of the Learning Games Network describes how the Game Design Tool Kit uses an instructional framework for STEM where teachers guide students through a four-phase design thinking cycle.

Video Games Are The Perfect Way To Teach Math, Says Stanford Mathematician
go.nmc.org/kei
> (Jordan Shapiro, *Forbes*, 29 August 2013.) A Stanford mathematician, founder of InnerTube games, discusses their role in helping players understand math concepts.

Time-to-Adoption: Two to Three Years

Immersive Learning Environments

Immersive learning environments (ILEs) are designed to mimic realistic situations as an approach to training individuals and providing them with the opportunity to practice their skills — whether online, via software, or face-to-face. A number of tools and services can be employed to construct such scenarios, but the goal is for the people involved to feel like they are demonstrating their knowledge in the real world. ILEs encompass a variety of learning techniques, including simulations and 3D virtual worlds, and generally incorporate ways for individuals to interact with each other. The latest research, including a study conducted by the United States National Library of Medicine, indicates that these types of environments bolster student engagement and accelerate knowledge and skill acquisition. Immersive learning environments are more commonplace in industry as a means of training employees in hands-on areas such as construction and medicine, and are already very widespread in the military. Gaining experience within the safety of a simulated environment can mitigate the risk of making life-threatening mistakes when performing the same tasks in the real world. More and more educational institutions are recognizing the merit of this tactic and integrating ILEs in their classrooms and programs as a means of making the learning more active and relevant.

Relevance for Teaching and Learning in STEM+ Education

- In engineering courses, students can design and build objects in a simulated environment to get an accurate sense of how the mechanisms will interact with each other.
- Medical students can practice high-stakes tasks more frequently, such as performing surgery and autopsies, before applying their skills in real situations.
- Student actions and behaviors in an online immersive learning environment can be tracked and analyzed to give instructors a better sense of how well students are grasping complex scientific concepts.

Immersive Learning Environments in Practice

- The Health Sciences department at Glyndŵr University in Wales established the Immersive Learning Environment, a large dome where students engage in various virtual and practical scenarios using a cutting-edge medical mannequin: go.nmc.org/glyn.
- Shaler Area Elementary School in Pennsylvania has transformed a classroom into an immersive STEM learning environment called IKS Titan, which engages learners in a mission-based simulation using iPads, a Promethean board, and other technology: go.nmc.org/penn.
- Students at Preston Middle School in Colorado are learning complex science concepts using virtual 3D models that have been integrated into the STEM curriculum to create immersive learning scenarios: go.nmc.org/pres.

For Further Reading

Here's What the Immersive, 3D Computer Interface of the Future Will Feel Like
go.nmc.org/imft
> (Christopher Mims, *Quartz*, 8 August 2013.) The videos of a virtual environments researcher convey the potential of 3D interfaces to offer users engaging ways to interact with data.

How Immersion in Virtual and Augmented Worlds Help Students in the Real World [Video]
go.nmc.org/dede
> (Chris Dede, Engage 2013 SXSWedu, 2013.) A professor from Harvard's Graduate School of Education explains how the evolution of mobile devices is relevant to the field of immersive interfaces, and demonstrates several examples of immersive projects in K-12 STEM settings.

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 such as shoes or a jacket. The benefit of wearable technology is that it can conveniently integrate tools that track sleep, movement, location, social media, and even new classes of devices that are seamlessly integrated with a user's everyday life and movements. Google's "Project Glass" is one of the most talked about current examples — the device resembles a pair of glasses, but with a single lens. A user can 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. Another is the Jawbone Up bracelet that tracks how you eat, sleep, and move. Other wearable technology already in the market includes clothing that can keep a mobile device charged via solar cells, allow interactions with a user's devices via sewn-in controls or touch pads, collect data on a person's movements, and much more.

Relevance for Teaching and Learning in STEM+ Education

- Google Glass is enhanced with augmented reality, which is intended to provide users with information about objects and locations they encounter as they move through their daily lives.

- Wearable cameras such as Memoto, which is designed to take photos every 30 seconds, will allow scientists to easily document an experiment, traditional observations, or setting.

- Wearable technology such as the UP wristband monitors users' everyday behaviors, including movement and sleep. In time, these data will comprise an enormous quantity of information for studies of behavior, motivation, physical health and well being, and medicine.

Wearable Technology in Practice

- Researchers at Melbourne's Bionic Institute are creating implantable bionic devices, including electrodes that can be inserted into the brain to detect abnormal activity and deliver treatment: go.nmc.org/brain.

- A robotic suit created by Koba Lab from Tokyo University of Science provides support to the wearer's back, shoulders, and elbows, enabling them to carry more weight and perform more difficult physical tasks: go.nmc.org/lift.

- A surgeon at The Ohio State University used Google Glass to record an ACL repair surgery live so that medical students were able to watch and learn from the surgery from his point of view: go.nmc.org/surg.

For Further Reading

8 Brilliant Concepts for the Future of Wearable Tech
go.nmc.org/frog
> (Mark Wilson, *Fast Company*, 20 February 2013.) The international design studio Frog conceptualizes the future of wearable technology in which wearable objects have a very small screen or no screen at all.

Google Glass and Wearable Tech: This is a Game-Changer, Not a Fad
go.nmc.org/nofad
> (Owen Williams, *The Next Web*, 11 March 2013.) Many concerns have surfaced about Google Glass, including privacy, but the author argues that it is important to recognize what a monumental technological step Google Glass is taking and the implications of using it.

Time-to-Adoption: Four to Five Years

Flexible Displays

When organic light emitting diode displays (OLED) began to enter mass markets in 2004, consumers found that the new screens were lighter, brighter, and more energy efficient. In contrast to traditional glass-based LCD units, these new displays could be manufactured on thin, pliable plastics, prompting the term "flexible displays." The popularity of OLED screens is largely due to their electroluminescence, which makes for more readable displays. The arrival of the world's thinnest OLED display in 2008 by Samsung introduced a screen that was pliable and could easily be folded — features that gave rise to ideas for unbreakable smartphones and bendable tablets. By 2009, popular news outlets including CBS and Entertainment Weekly were including "video in print" inserts in smaller circulations of their magazines, demonstrating the new technology. In late 2012, LG, Samsung, and Philips, among other major players in the electronics industry, announced plans to mass-produce flexible displays by 2013, and Apple recently patented its own pliable display. As flexible displays gain traction in the consumer market, researchers, inventors, and developers are experimenting with possible applications for teaching and learning. Opportunities offered by flexible OLED screens in education settings are being considered for e-texts, e-readers, and tablets. Additionally, flexible displays can wrap around curved surfaces, allowing for the possibility of scientific and other instruments with built-in instruction manuals.

Relevance for Teaching and Learning in STEM+ Education

- Flexible screens can easily be attached to objects or furniture, regardless of their shape, and can even be worn — making them far more adaptable and portable for science experimentation than standard computer screens and mobile devices.

- Prototypes for flexible displays in the form of "e-paper" that can be crumpled up and discarded just like real paper may cause e-book manufacturers and others to rethink the construction and applications of digital textbooks and e-readers.

Flexible Displays in Practice

- The Flexible Display Center at Arizona State University was established to advance the development of full-color, video quality, flexible display and flexible electronics technology in order to collaborate with partners across industries: go.nmc.org/asufl.

- Queen's University, in partnership with Plastic Logic and Intel Labs, has created a paper thin tablet that is bendable and stackable: go.nmc.org/papertab.

- Researchers from UCLA's Henry Samueli School of Engineering and Applied Science developed a transparent, elastic organic light-emitting device for electronics, allowing them to be repeatedly stretched, folded, and twisted: go.nmc.org/ucl.

For Further Reading

Flexible Curved Displays to Top $27 Billion by 2023
go.nmc.org/flxbill
> (R. Colin Johnson, *EE Times*, 18 September 2013.) A report reviews over 260 companies and research institutes that are developing flexible and curved display technologies and analyzes the challenges that face development.

Want to Know When Your Phone will become Your Flexible Friend?
go.nmc.org/frflx
> (Simon Hill, *Techradar*, 12 July 2013.) This article provides background information on flexible displays and explores the latest data that signals the oncoming flexible smartphone boom.

Time-to-Adoption: Four to Five Years
The Internet of Things

The Internet of Things conveys information communicated by network aware objects that connect the physical world with the world of information through the web. It does so through TCP/IP, the set of standards that enables network connections and specifies how information finds its way to and from the myriad of connections it contains. TCP/IP was formulated in the 1970s by Vinton Cerf and Robert E. Kahn. The advent of TCP/IP v6, launched in 2006, added enormous new addressing capabilities to the Internet, and enabled objects and the information they might carry in attached sensors or devices to be addressable and searchable across the web. This expanded address space is particularly useful for tracking objects that monitor sensitive equipment or materials, point-of-sale purchases, passport tracking, inventory management, identification, and similar applications. Embedded chips, sensors, or tiny processors attached to an object allow helpful information about the object, such as cost, age, temperature, color, pressure, or humidity to be transmitted over the Internet. This simple connection allows remote management, status monitoring, tracking, and alerts if the objects they are attached to are in danger of being damaged or spoiled. Traditional web tools allow objects to be annotated with descriptions, photographs, and connections to other objects, and any other contextual information. The Internet of Things makes 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 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.

The Internet of Things in Practice
- In a partnership between the UK Maker community and Falmouth University's Academy of Innovation and Research, formal residencies enables designers to invent Internet of Things-enabled objects, such as a music memory box for dementia patients: go.nmc.org/threecon.
- A research team at Columbia University attached energy harvesting devices to 40 individuals to analyze the power available in an effort to harvest energy from human motion to power devices and objects so they can connect with each other: go.nmc.org/moti.
- University of Washington engineers discovered a new way to repurpose existing wireless signals into both a source of power and a communication medium, which will allow smart objects to connect with each other without batteries: go.nmc.org/nob.

For Further Reading
10 Things You Should Know About the Internet of Things
go.nmc.org/10things
(Patrick Gray, *TechRepublic,* 10 January 2013.) A helpful list of relevant ideas related to the Internet of Things is provided, which includes descriptions of its uses and business values.

What's Holding Up The Internet Of Things
go.nmc.org/hol
(Brian Proffitt, *ReadWriteWeb*, 14 June 2013.) The author discusses barriers to imminent advancements in the field, including a lack of consensus around a standard protocol.

Time-to-Adoption: Four to Five Years

Machine Learning

Machine learning refers to computers that are able to act and react without being explicitly programmed to do so. Computer scientists and engineers are developing systems that not only intake, retrieve, and interpret data, but also learn from it. To do this, the machine must make a generalization, using algorithms to perform accurately on new examples after being trained on a different learning data set — much like a human learns from experiences and uses that knowledge to respond appropriately in a different encounter. In this sense, machine learning is widely considered by many researchers and thought leaders to reflect an emerging approach towards human-like artificial intelligence. Practical speech recognition, semantic applications, and even self-driving cars all leverage machine learning. A recent incarnation of machine learning is software called Xapagy, which improvises dialogue and plot moves in stories fed to it by users. The potential of machine learning for education is vast, facilitating altogether smarter technology that has the accuracy of a computer and the adaptability of the most intelligent human beings.

Relevance for Teaching and Learning in STEM+ Education

- Machine learning models can potentially sort through learner-contributed observations about the world around them and create visualizations that identify crucial patterns.

- Software that employs machine learning to detect patterns in written work, speech, and other actions could better adapt to students' learning styles and needs.

- Ultimately, machine learning promises to enable scientists and researchers to communicate more authentically with their devices — even in improvised ways, just as a colleague or friend would. It is easily foreseeable that students will collaborate with machines on projects.

Machine Learning in Practice

- At the University of California, Berkeley, a team developed a machine learning telescope model to automatically detect changes pointing to supernova occurrences: go.nmc.org/wis.

- Researchers at MIT created a system that allows people to see the world the way an object-recognition system does, taking an image, translating it into a mathematical representation, and then using new algorithms to convert it back into a conventional image: go.nmc.org/lik.

- The University of Texas is using machine learning techniques to develop tools that automatically analyze and assemble a short story from the recorded footage produced by devices that shoot egocentric video, such as Google Glass: go.nmc.org/utex.

For Further Reading

Bringing 'Common Sense' to Text Analytics
go.nmc.org/comsen
> (Rob Matheson, *MIT News*, 24 September 2013.) Through the MIT Media Lab, Catherine Havasi is working to bring common sense to text analytics in her startup, Luminoso Technologies, which aims to mine and analyze online text to identify patterns and underlying themes.

The Man Behind the Google Brain: Andrew Ng and the Quest for the New AI
go.nmc.org/goobra
> (Daniela Hernandez, *Wired*, 7 May 2013.) The Google Brain movement, led by Stanford professor Andrew Ng, seeks to meld computer science with neuroscience in a new field known as deep learning, so that machine learning will mimic the way human brains learn.

Time-to-Adoption: Four to Five Years

Virtual Assistants

As voice recognition and gesture-based technologies advance and more recently, converge, we are quickly moving away from the notion of interacting with our devices via a pointer and keyboard. Virtual assistants are a credible extension of work being done with natural user interfaces (NUI), and the first examples are already in the marketplace. The concept builds on developments in interfaces across the spectrum of engineering, computer science, and biometrics. The Apple iPhone's Siri and Android's Jellybean are recent mobile-based examples, and allow users to control all the functions of the phone, participate in lifelike conversations with the virtual assistant, and more. A new class of smart televisions are among the first devices to make comprehensive use of the idea. While crude versions of virtual assistants have been around for some time, we have yet to achieve the level of interactivity seen in Apple's classic video, Knowledge Navigator. Virtual assistants of that caliber, and their applications for learning are clearly in the long-term horizon, but the potential of the technology to add substance to informal modes of learning is compelling.

Relevance for Teaching and Learning in STEM+ Education

- Accessible through natural user interfaces, virtual assistants can be designed specifically to aid blind, deaf, and otherwise disabled learners.
- One use case for virtual assistants already in development is that of real-time translators, increasing the scope and depth of collaboration between institutions globally.
- Virtual assistants can access information from email accounts, personal calendars, and LMS to help students and faculty better manage their time and coordinate their work.

Virtual Assistants in Practice

- At the San Mateo Medical Center, aspects of physical therapy are being carried out by a digital avatar via Nuance, a company that develops virtual assistant software: go.nmc.org/sanmt.
- Carnegie Mellon University created an open source toolkit for speech recognition on Kindle devices called VAGUE, which allows users to navigate the reader, launch various tools, and prompt more actions by writing a new script: go.nmc.org/sphinx.
- Designed by the University of Cambridge, Zoe is a virtual assistant avatar that can express a full range of emotions. Current research efforts focus on using this technology to work with autistic and deaf children: go.nmc.org/zoe.
- The University of Virginia Health System selected M*Modal, a speech recognition engine, to facilitate the creation, management, and sharing of electronic medical records: go.nmc.org/mmodal.

For Further Reading

Beyond the GUI: It's Time for a Conversational User Interface
go.nmc.org/cuiwi
> (Ron Kaplan, *WIRED*, 21 March 2013.) Ron Kaplan — a linguist, mathematician, and technologist — predicts the imminent emergence of the conversational user interface, which is based on voice-recognition and machine learning technologies.

New Virtual Assistant Anticipates Needs During Conversation
go.nmc.org/needs
> (Tyler Falk, *Smart Planet*, 18 January 2013.) The author describes the iPad app, MindMeld, which analyzes and understands the content of online conversations in order to provide useful information.

Top Ten Trends Impacting Technology Decisions

The technologies featured in the NMC Horizon Project are embedded within a contemporary context that reflects the realities of its 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 affecting the practice of teaching or learning in education, and uses these as a lens for its work in predicting the uptake of emerging technologies in whatever sector or region 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 of an impact they are likely to have on education in the next five years. The following ten trends have been identified as key drivers of technology adoptions in STEM+ education for the period of 2013 through 2018; they are listed here in the order they were ranked by the 2013 Horizon.STEM Advisory Board.

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 hybrid learning models can leverage the online skills learners have already developed outside of their school or university experiences. Online learning environments can offer different affordances than physical campuses, including opportunities for increased 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) Citizen science projects increasingly provide formal students and lifelong learners the opportunity to participate and learn in real STEM projects. With an increasing amount of attention from institutions on providing students with real world experience, citizen science has emerged as a pathway to authentic, collaborative learning. Citizen science refers to crowdsourced research that is generated by nonprofessional scientists. Ongoing projects such as iNaturalist, Journey North, Wildlife Watch, and several from the Cornell Laboratory of Ornithology engage participants in the process of gathering real observations and analyses. It is imaginable that outside of these large-scale, public projects, learning environments could be set up similarly within institutions to encourage students to think about how their knowledge can be applied while contributing to an ecosystem of scientific data.

3) As the abundance of resources and relationships made easily accessible via the Internet grows, we are continuously challenged 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 and work is again at the forefront. Universities have always been seen as the gold standard for educational credentialing, but emerging certification programs from other sources are eroding the value of that mission.

4) Increasingly, students want to use their own technology for learning. Utilizing a specific device has become something very personal — an extension of someone's personality and learning style. For example, the choice one makes for the iPhone or Android reflects a person's overall sensibilities. 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 advanced equipment in their personal lives than at school.

5) From rapid prototyping with 3D printers to building simple circuits and robots, "Making" is now more affordable and accessible than ever. Creativity, design, and engineering are making their way to the forefront of educational considerations as tools such as 3D printers, robotics, and 3D modeling applications become available to more people. This disruptive trend has largely been fueled by the Maker movement, which consists of artists, technology enthusiasts, and others who share a passion for creating. Making addresses the sorts of STEM skills that many educators and policymakers consider most important to productivity in the 21st century.

6) Cloud-based tools are enabling rapid innovation across educational environments. Free or very inexpensive services such as Google Apps, YouTube, and others have become pervasive, enabling students of all ages to instantly share media and collaborate on projects — from anywhere there is Internet access. Additionally, the content shared across cloud-based platforms can be re-mixed and embedded into all kinds of online learning environments.

7) Computer-based assessment and feedback, along with ICT support for personalization, are becoming increasingly important. As more learning takes place online, particularly across STEM+ education, new forms of assessments are being integrated into the digital environments. Institutions are evolving from the days of hand-grading papers and exams to more 21st century practices, and there is a need to maintain and even increase the level of personalization given to the evaluation of each student's work. Work that is conducted online by massive numbers of students is not always conducive to human assessments. Products and services that automatically generate data about individual student performance are becoming more prevalent.

8) 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" continues its diffusion as a buzzword in education, and it is increasingly important to understand the definition. Often mistakenly equated only with "free," open education advocates are working towards a common vision that defines "open" as free, copiable, remixable, and without any barriers to access or interaction.

9) People expect to be able to work, learn, and study whenever and wherever they want. Life in a busy world where learners must balance demands from home, work, school, and family poses a host of logistical challenges with which today's ever more mobile students must cope. Work and learning are often two sides of the same coin, and people want easy and timely access not only to the information on the network, but also to tools, resources, and up-to-the-moment analysis and commentary. These needs, as well as the increasingly essential access to social media and networks, have risen to the level of expectations. The opportunities for informal learning in the modern world are abundant and diverse, and greatly expand on earlier notions like "just-in-time" or "found" learning.

10) Massive open online courses are being widely explored as alternatives and supplements to traditional university courses, especially in STEM+ disciplines. Led by the successful early experiments of world-class institutions, MOOCs have captured the imagination of senior administrators and trustees like few other education innovations have. High profile offerings are being assembled under the banner of institutional efforts like edX, and large-scale collaborations like Coursera, the Code Academy, and in Australia, Open2Study. As the ideas evolve, MOOCs are seen as an 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 such as micro-credit.

Top Ten Most Significant Challenges

Along with the trends discussed in the preceding section, the advisory board noted a number of important challenges faced in STEM+ education. Like the trends, the 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 or learning in STEM+ education in the coming five years are listed here, in the order of importance assigned them by the advisory board.

1) 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. The biggest barrier to personalized learning, however, is that scientific, data-driven approaches to effectively facilitate personalization have only recently begun to emerge.

2) Appropriate metrics of evaluation lag 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 more and more 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.

3) Most academics are not using new and compelling technologies for learning and teaching, nor for organizing their own research. Many researchers have not had training in basic digitally supported teaching techniques and do not participate in the professional development opportunities that would provide them. This is due to several factors, including a lack of time and a lack of expectations that they should. Many think a cultural shift will be required before there is widespread use of more innovative organizational technology. Some educators are simply apprehensive about working with new technologies, or believe that they will get in the way of the learning. Adoption of progressive pedagogies, however, is often enabled through the exploration of emerging technologies. Many educators feel that an attitudinal change among academics is imperative.

4) Faculty training still does not acknowledge the fact that digital media literacy continues its rise in importance as a key skill in every STEM discipline and profession. Despite the widespread agreement on the importance of digital media literacy, training in the supporting skills and techniques is rare in teacher education and non-existent in the preparation of faculty. As instructors 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.

5) 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.

6) New models of education are bringing unprecedented competition to the traditional models of higher education. Across the board, institutions are looking for ways to provide a high quality of service and more learning opportunities. MOOCs are at the forefront of these discussions, enabling students to supplement their education and experiences at brick-and-mortar institutions with increasingly rich, and often free, online offerings. As these new platforms emerge, however, there is a need to frankly evaluate the models and determine how to best support collaboration, interaction, and assessment at scale. Simply capitalizing on new technology is not enough; the new models must use these tools and services to engage students on a deeper level.

7) MOOCs need to be rethought as open ongoing connectivist communities for open teaching and open research. Connectivism refers to a model of learning where social and cultural interactions are the focus, and individuals bring their own personal work experience and knowledge to the environment to add to a continuously expanding ecosystem of learning. While this manner of open learning is already well-established, open teaching and research are new concepts that could leverage this notion of crowdsourcing and collective intelligence to build new pedagogies and practices, along with gaining new findings and insights for science studies. Learning materials can be created within these communities and used in classrooms all over the world.

8) There is still much to be done before we are teaching STEM not as a set of facts, but instead as a way of knowing. Traditional forms of demonstrating newly acquired STEM knowledge have been through assignments where students are often just reciting facts. This is in contrast with the arts and humanities, where there is generally an opportunity to creatively interpret the subject matter. In a world where scientific concepts are constantly changing as new evidence is discovered, simply memorizing facts does not contribute to fostering curiosity among students to continuously explore these changes as they arise. Similar to more creative disciplines, new interpretations in science should be welcomed discourse in institutions.

9) Our organizations are not set up to promote innovation in teaching. Innovation springs from the freedom to connect ideas in new ways. Our schools and universities generally allow us to connect ideas only in prescribed ways — sometimes these lead to new insights, but more likely they lead to rote learning. Current organizational promotion structures reward research instead of innovation and improvements in teaching and learning. The major consequences of student evaluations on teaching, as well as the direct impact on promotion and career options, translates to big risks associated with the failure of innovations and leaves little space for experimentation.

10) Math needs to be redesigned, and teaching coding should be a major part of that new learning course. Many view current math curriculum as stagnant, with students still solving equations and problems in the same manner. According to Code.org, there will be more than 1.4 million computer jobs in demand in 2020; there is a need for math students to acquire computer science skills. Programming is being incorporated into many institutions as elective courses, but only a few schools have integrated coding directly into math and other disciplines. Rather than relying on graphing calculators and notebooks, students can program shortcuts and design formulas.

Methodology

The process used to research and create the *Technology Outlook for STEM+ Education 2013-2018: An NMC Horizon Project 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 2013-2018* 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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2013 Horizon.STEM Advisory Board