NMC Horizon Report > 2015 K-12 Edition

The *NMC Horizon Report: 2015 K-12 Edition* examines emerging technologies for their potential impact on and use in teaching, learning, and creative inquiry in schools.

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The *NMC Horizon Report: 2015 K-12 Edition*
is a collaboration between The NEW MEDIA CONSORTIUM and the CONSORTIUM FOR SCHOOL NETWORKING.

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Executive Summary

What is on the five-year horizon for K-12 schools worldwide? Which trends and technologies will drive educational change? What are the challenges that we consider as solvable or difficult to overcome, and how can we strategize effective solutions? These questions and similar inquiries regarding technology adoption and transforming teaching and learning steered the collaborative research and discussions of a body of 56 experts to produce the *NMC Horizon Report: 2015 K-12 Edition*, in partnership with the Consortium for School Networking (CoSN). The *NMC Horizon Report* series charts the five-year horizon for the impact of emerging technologies in school communities across the globe. With more than 13 years of research and publications, it can be regarded as the world's longest-running exploration of emerging technology trends and uptake in education.

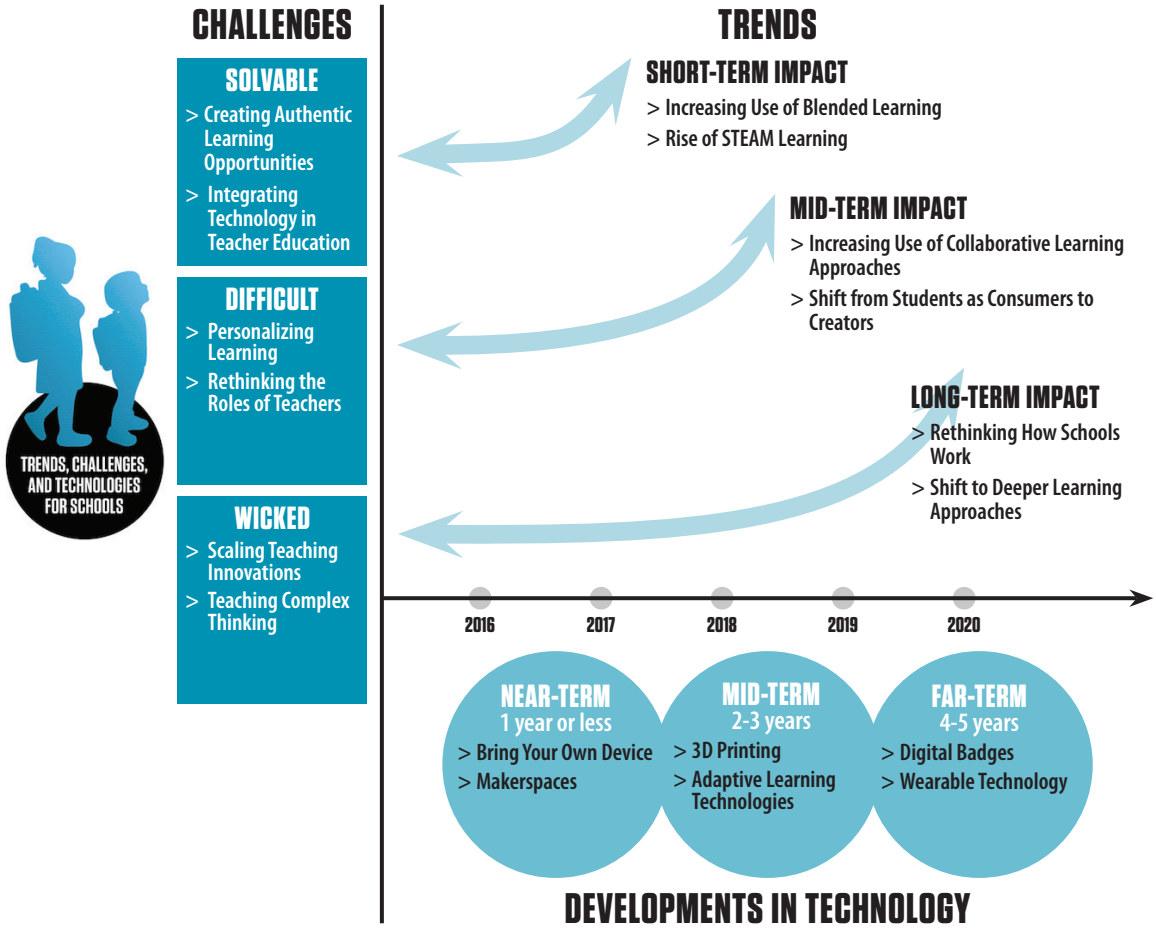
The experts agreed on two long-term trends: rethinking how schools work in order to bolster student engagement and drive more innovation, as well as shifting to deeper learning approaches, such as project- and challenge-based learning. These are just two of the 18 topics analyzed in the *NMC Horizon Report: 2015 K-12 Edition*, indicating the key trends, significant challenges, and important technological developments that are very likely to impact changes in K-12 education across the world over the next five years.

Regarding the challenges for schools, integrating technology in teacher education is considered solvable. K-12 leaders are already addressing the root problem by developing new models for training and professional development. Finnish teachers, for example, are turning to "Edukata," a participatory design model that encourages them to investigate new technology-enabled pedagogies such as the flipped classroom and then implement them effectively in their classrooms. On the other hand, the experts identified the task of scaling these teaching innovations as a wicked challenge — one that is impossible to define let alone solve. Teachers do not often have the adequate support systems to transition their good ideas beyond their own classrooms. The end goal of solving this challenge will be to diffuse the most effective pedagogies throughout entire schools, districts, and nations.

In view of the trends and challenges observed, the panel also signalled the important developments in technology that could support these drivers of innovation and change. Bring Your Own Device (BYOD) and makerspaces are expected to be increasingly adopted by schools in one year's time or less to make use of mobile learning and cultivate environments where students take ownership of their education by doing and creating. The time-to-adoption for 3D printing and adaptive learning technologies are estimated within two to three years, while digital badges and wearable technology are expected to be mainstream in schools within four to five years.

The three key sections of this report constitute a reference and straightforward technology planning guide for educators, school leaders, administrators, policymakers, and technologists. It is 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 creative inquiry in K-12 education across the globe. Education leaders worldwide look to the NMC Horizon Project and both its global and regional reports as key strategic technology planning references, and it is for that purpose that the *NMC Horizon Report: 2015 K-12 Edition* is presented.

Topics from the *NMC Horizon Report > 2015 K-12 Edition*



Introduction

The *NMC Horizon Report: 2015 K-12 Edition* was produced by the NMC in collaboration with CoSN. The internationally recognized *NMC Horizon Report* series and regional *NMC Technology Outlooks* are part of the NMC Horizon Project, a comprehensive effort established in 2002 by the NMC that identifies and describes important developments in technology likely to have a large impact over the coming five years in education around the globe. Each of the four global editions of the *NMC Horizon Report* — higher education, K-12 education, museum, and library — highlights six emerging technologies or practices that are likely to enter mainstream use within their focus sectors over the next five years. Key trends and challenges that will affect current practice over the same period frame these discussions.

In the pages that follow, 18 topics carefully selected by the 2015 Horizon Project K-12 Expert Panel related to the educational applications of technology are examined, all of them areas very likely to impact technology planning and decision-making over the next five years (2015-2019). Six key trends, six significant challenges, and six important developments in educational technology are placed directly in the context of their likely impact on the core missions of schools, and detailed in succinct, non-technical, and unbiased presentations. Each has been tied to essential questions of relevance, policy, leadership, and practice.

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

The third section, in which six important developments in educational technology are described, is ultimately framed by these trends and challenges. The adoption or abandonment of these technologies by schools will be very much determined by the responses taken across the world to these drivers of and obstacles to innovation and change.

Each topic closes with an annotated list of suggested readings and additional examples that expand on the discussion in the report. Throughout the report, supporting research for every topic is referenced in the form of endnotes. Readers are encouraged to further explore the articles, papers, and media that often elaborate on key points made in this report by visiting the websites listed in the endnotes section.

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

The process used to research and create the *NMC Horizon Report: 2015 K-12 Edition* is rooted in the methods used across all the research conducted within the NMC Horizon Project. All editions of the *NMC Horizon Report* are informed by both primary and secondary research. Dozens of meaningful trends, challenges, and important developments in technology are examined for possible inclusion in the report for each edition.

Every report draws on the considerable expertise of an international expert panel that first considers a broad set of important trends, challenges, and developments in educational technology, and then examines each of them in progressively more detail, reducing the set until the final listing of trends, challenges, and technologies is selected. This process takes place online, where it is captured in the NMC Horizon Project wiki. The wiki is intended to be a completely transparent window into the work of the project, one that not only provides a real-time view of the work as it happens, but also contains the entire record of the process for each of the various editions published since 2006. The wiki used for the *NMC Horizon Report: 2015 K-12 Edition* can be found at k12.wiki.nmc.org.

The panel was composed of 56 education and technology experts from 22 countries on six continents this year; their names and affiliations are listed at the end of this report. The panel as a whole was intended to represent a wide range of backgrounds and interests, yet with each member bringing a particularly relevant expertise. Despite their diversity of backgrounds and experience, they share a consensus view that each of the profiled topics is going to have a significant impact on the practice of K-12 education around the globe over the next five years.

The panel was composed of 56 education and technology experts from 22 countries on six continents this year.

The procedure for selecting the topics in the report is based on a modified Delphi process refined over the now 13 years of producing the *NMC Horizon Report* series, and began with the assembly of the panel. The panel represents a wide range of backgrounds, nationalities, and interests, yet each member brings a relevant expertise. Over the decade of the NMC Horizon Project research, more than 1,300 internationally recognized practitioners and experts have participated on the panels; in any given year, a third of panel members are new, ensuring a flow of fresh perspectives each year. Nominations to serve on the expert panel are encouraged; see go.nmc.org/panel.

Once the panel for a particular edition is constituted, their work begins with a systematic review of the literature — press clippings, reports, essays, and other materials — that pertains to emerging technology. Members are provided with an extensive set of background materials when the project begins, and are then asked to comment on them, identify those that seem especially worthwhile, and add to the set. The group discusses existing applications of emerging technology and brainstorms new ones. A key criterion for the inclusion of a topic in this edition is its potential relevance to teaching, learning, and creative inquiry in K-12 education. A carefully selected set of RSS feeds from hundreds of relevant publications ensures that background resources stay current as the project progresses. They are used to inform the thinking of the participants.

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

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

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

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

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

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

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

From the comprehensive list of trends, challenges, and developments in educational technology originally considered for any report, the dozen that emerge at the top of the initial ranking process in each area are further researched and expanded. Once these interim results are identified, the group explores the ways in which these topics impact teaching and learning in schools. A significant amount of time is spent researching real and

potential applications for each of the topics that would be of interest to practitioners. The semi-finalist topics of the interim results are then ranked yet again, this time in reverse. The final topics selected by the expert panel are those detailed here in the *NMC Horizon Report: 2015 K-12 Edition*.

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, which can be found at k12.wiki.nmc.org.

Key Trends Accelerating Technology Adoption in K-12 Education

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

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

The NMC Horizon Project model derived three meta-dimensions that were used to focus the discussions of each trend and challenge: policy, leadership, and practice. Policy, in this context, refers to the formal laws, regulations, rules, and guidelines that govern schools; leadership is the product of experts' visions of the future of learning, based on research and deep consideration; and practice is where new ideas and pedagogies take action, in schools and related settings.

Policy. While all of the identified trends had policy implications, two trends in particular are expected to have a strong impact on policy decisions in the next five years. Deep learning approaches has emerged as a major topic of interest to national governments and schools, but requires effective policy to become mainstream in practice. Deeper learning includes models such as project- and challenge-based learning, which connect curriculum to life outside the classroom. The Next Generation Science Standards is a US education policy promoting both academic learning and real-world application that is accelerating experimentation in this area.[1]

Likewise, the expert panel believes that blended learning designs, currently on the rise in schools in the developed world, will reach its maximum impact in the next one to two years. The International Association for K-12 Online Learning (iNACOL)'s Center for Policy Advocacy has developed recommendations for state policymakers considering new learning models. Their latest brief focuses on five critical areas that include creating competency-based education systems, supporting innovative educators, and more.[2]

These trends, which the members of the expert panel agreed are very likely to drive technology planning and decision-making over the next five years, are sorted into three movement-related categories.

Leadership. Although there are leadership implications for all the identified trends that are discussed in the following pages, two trends stand out as unique opportunities for vision and leadership. The rise of STEAM learning, a more multi-disciplinary take on STEM learning that includes arts and humanities activities, is being accelerated by dialog, conferences, and discussions among school leaders. In the US, the National Association for Music Education (NAfME) recently sponsored a STEAM-themed event that demonstrated how music education cultivates important skills for a 21st century workforce.

A long-term impact trend is reinventing how traditional schools operate. Innovative learning approaches require removing limitations of traditional bell schedules and

grades while encouraging the creative application of technology. Finland is emerging as a leader in rethinking how the school day is structured. Their school system has alternative methods of evaluation that deemphasizes quantification and scoring by not awarding grades prior to the fifth grade. Instead, the focus is more on projects and active demonstrations of knowledge acquisition.[3]

Practice. Each of the six trends identified by the expert panel has numerous implications for teaching and learning practice, and current examples are easy to find. The increasing use of collaborative learning approaches, highlighted as one of two developing mid-term impact trends in the following pages, is leveraging technology to connect teachers and students inside and outside of the classroom. The Global Book series created at Avenues: The World School in New York, for example, is a group of e-books co-authored by students and teachers from schools in different countries.[4]

All over the world, schools have been shifting the roles of students from passive consumers of content and knowledge to creators of it. By integrating digital tools in lessons, students are more fluently producing media and prototypes, leading to greater engagement with learning. At ChemED Ireland 2014, Irish teachers shared how an activity in creating stop motion animation and filmmaking enabled learners to grasp complex chemistry concepts.[5]

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

Rethinking How Schools Work

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

There is a focused movement to reinvent the traditional classroom paradigm and rearrange the entire school experience — a trend that is largely being driven by the influence of innovative learning approaches. Methods such as project-[6] and challenge-based learning[7] call for school structures that enable students to move from one learning activity to another more organically, removing the limitations of the traditional bell schedule. The multidisciplinary nature of these contemporary approaches has popularized the creative application of technology and fostered innovative designs of school models that link each class and subject matter to one another. As learning becomes more fluid and student-centered, some teachers and administrators believe that schedules should be more flexible to allow opportunities for authentic learning to take place and ample room for independent study.[8] Changing how learning takes place in classrooms is also requiring shifts in the business models of schools, which are increasingly becoming more agile and open to trying new approaches.[9]

Overview

This trend is largely a response to the overly structured nature of a typical school day, which some believe hampers learning.[10] Traditionally, bells have signified the beginning and end of each day, ushering students from one class to the next. In many ways, the bell symbolizes the separation of disciplines, making a clear statement that each should be kept disparate. In the past few years, many teachers have made progress toward bolstering interdisciplinary learning, also commonly referred to as integrated studies. *Edutopia* describes this model as combining "curriculum from two or more disciplines, allowing students to see how ideas are connected."[11] They point to collaboration, critical thinking, and knowledge retention as three positive outcomes for students. Technology use is at the heart of this design as activities such as integrating 3D printing in science classes and media production into humanities courses become more pervasive. The goal is for students to understand the various intersections between technology and virtually any subject matter, acquiring a skillset that is desired in the contemporary workforce.

Another way that schools are updating their structure is by adjusting start times. A recent paper from the American Academy of Pediatrics recommends that teenagers start class after 8:30 am, citing sleep deprivation as a major factor in disengagement and decreased performance at school.[12] As a response, more schools are making their first classes begin later. The US Department of Education reports that 57% of public high schools start after 8:30 am. The Director of the Center for Applied Research and Education Improvement at the University of Minnesota stated that statistical evidence shows improved attendance, along with better performance in English, math, social studies, and science.[13] Moreover, an increasing number of online courses and virtual schools including James Madison High School have even made the timing of school a moot point as many of these experiences are self-paced.[14]

Part of rethinking how schools work is redefining what skill mastery looks like. Integrating technology into the curriculum is putting a new twist on how teachers and students approach knowledge acquisition. In music class, for example, students may be expected to learn how to play instruments and be assessed based on their performances. However, researchers at Drexel University believe that incorporating more technology in K-12 music education can redefine what it means for learners to be musical. Exposing students to computer-based tools, which are standard in the music industry, can deeply engage them in the subject matter and reveal to them different pathways for mastering music.[15] These practices call into question traditional modes of assessment that evaluate mastery in terms of test scores, accuracy, and other straightforward measurements.

Implications for Policy, Leadership, or Practice

At a local level, many schools have been revising their technology and related policies to be more inclusive of the student voice. At Boston Public Schools, students are invited to share their perspectives by serving on the Boston Student Advisory Council.[16] In addition to having a say in policy matters, student representatives report back to their classmates about relevant citywide issues. An Arizona middle school teacher allowed his students to design the classroom BYOD policy and the results showed their maturity and sense of responsibility. One of the components the students included was that

their devices be used explicitly for learning during class.[17] Replacing the traditional paradigm of the school experience also requires a consolidated vision of what 21st century schools look like so that national directives can support new ideas. President Obama's ConnectED initiative is an effort to train teachers with the skills they need to integrate new technologies in the classroom that support more personalized and flexible learning.[18]

To reimagine traditional school structures, school leaders can turn to what is widely perceived to be a successful school system in Finland.[19] At Finnish schools, alternative forms of assessment include students' own self-reflections and they do not receive grades prior to fifth grade, deemphasizing the quantification of learning.[20] Schools there are not ranked and receive equal funding, making school test scores and family's financial status obsolete factors.[21] Much work is also being done globally by K-12 educators and researchers to redefine assessment around creativity. The OECD's landmark paper, "First Steps Towards New Forms of Formative Assessments," makes the case for a five creative dispositions model that evaluates the extent of creativity qualities in students and includes inquisitive, persistent, and imaginative among them.[22] Such a rubric gives different kinds of students an opportunity to be successful in school.

In California, Da Vinci Schools epitomizes unconventional school structures; they have employed a project-based learning approach in which students learn by doing. Students spend their days working in teams to create a final product, mastering skills such as critical thinking, collaboration, and communication along the way. In this environment, technology use is key. One team, for example, learned about circular motion and projection paths by developing flash animation movies. Student knowledge is then assessed through public presentations of learning, exhibitions, and digital portfolios, in addition to tests and quizzes.[23] Similarly, High Tech High (HTH) is an integrated network of schools that emphasizes students working on projects outside of the classroom. HTH students connect their studies through fieldwork, community service, internships, and consulting with outside experts. They also routinely create media and exhibit it for real audiences.[24]

For Further Reading

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

Finland Schools: Subjects Scrapped and Replaced with 'Topics' as Country Reforms Its Education System
go.nmc.org/subj
(Richard Garner, *The Independent*, 20 March 2015.) Finland's National Curriculum Framework has created a requirement beginning in August 2016 that a certain number of a school's traditional subject-based classes like history and math be replaced with interdisciplinary classes that are based on broader topics, such as the EU or vocation-specific lessons. > *Policy*

Entrepreneurs Are Changing the Future of Education by Starting New Schools in New Orleans
go.nmc.org/entrepre
(Adriana Lopez, *Forbes*, 27 March 2015.) 4.0 Schools is a New Orleans-based nonprofit incubator for education-based startups that seeks to build a community of people re-imagining the future of schools. Bricolage Academy and Rooted School demonstrate two new experimental designs. > *Leadership*

Inside the Schools that Dare to Break with Traditional Teaching
go.nmc.org/dare
(Matthew Jenkin, *The Guardian*, 11 February 2015.) A handful of schools are breaking from traditional models to create more student-centered learning models including Quest to Learn School in New York, which leverages game-based learning. > *Leadership*

This Innovative District Lets Students Choose How to Learn
go.nmc.org/stuchoo
(Dennis Pierce, *eSchool News*, 7 April 2015.) Taylor County Schools allows students to choose from among six learning pathways that represent different instructional models, including traditional, online, peer-led, self-paced, project-based, or a personalized combination.
> *Leadership*

How to Motivate Students to Take Ownership of Their Learning
go.nmc.org/owner
(Angela Watson, *The Cornerstone*, January 2015.) This post explains how asking the question, "What are you doing in your classroom now that you could turn over to your students to do themselves?" helps students take charge of their own learning. > *Practice*

What Classrooms Can Learn from the Google Campus
go.nmc.org/fairchild
(Elijah Wolfson, *Newsweek*, 8 September 2014.) The agile classroom design at Bridgeport's Fairchild Wheeler Interdistrict Magnet Campus resembles a Silicon Valley workspace and represents a shift from a traditional lecture-centered model to collaborative learning.
> *Practice*

Shift to Deeper Learning Approaches

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

There has been a long-term emphasis in the classroom on deeper learning approaches, defined by the Alliance for Excellent Education as the delivery of rich core content to students in innovative ways that allow them to learn and then apply what they have learned.[25] Project-based learning, problem-based learning,[26] inquiry-based learning,[27] and similar methods foster more active learning experiences, both inside and outside the classroom. As technologies such as tablets and smartphones are more readily accepted in schools, educators are leveraging these tools to connect the curriculum with real life applications. These approaches are decidedly more student-centered, allowing learners to take control of how they engage with a subject. In advance examples of this trend, students are able to brainstorm solutions to pressing local and global problems and begin to implement them in their communities.

Overview

Deeper learning combines the goals of standardized testing with soft skills such as mastering communication, collaboration, and self-directed learning. The ultimate goal is to assess a student's performance through more than just test scores.[28] At Impact Academy of Arts and Technology in California, educators create portfolio-based performance assessments to boost college readiness. Students compile portfolios that demonstrate mastery in research, inquiry, analysis, and creative expressions and defend them in order to move from the school's lower division to upper division and on to graduation. The results are compelling; since 2012, 90% of Impact's students have enrolled in at least a two-year college.[29] A recent report by the American Institutes for Research supports the impact of this approach, citing that students at deeper learning schools achieved higher scores on the OECD PISA-Based Test for Schools and were more likely to graduate on time.[30]

Project-based learning is a deeper learning approach that is seen as a way to address gaps in science education. The SRI International report "Curriculum Materials Make a Difference for Next Generation Science Learning" studied the impact of using a project-based learning curriculum versus a standard textbook in grade six students.[31] The study cited that students who participated in project-based science curriculum outperformed students using just a traditional textbook. Their findings also revealed that it worked for a broad range of students; girls and boys, and students from diverse racial, ethnic, and socioeconomic backgrounds learned at similar rates.[32] Indeed, project-based learning is stated to have a number of benefits that can enhance teaching and learning; they include providing real-world relevance, longer retention and ability to apply knowledge of lessons learned, preparation for the 21st century work environment, and exposure to using technology to solve problems.

Similarly to project-based learning, inquiry-based learning is proving to be an effective pedagogical approach to deeper understanding of curriculum. Inquiry-based learning involves students constructing their own knowledge based on personal experiences and explorations. It is a method of learning by doing that parallels the work of scientists as they pursue scientific inquiry. With appropriate guidance, research has shown that inquiry-based activities can improve student learning in a range of subjects beyond STEM.[33] To be successful in this approach, school leaders recommend educators engage in professional development to develop their own inquiry skills, formulate a classroom community of inquiry to show students how to respect the opinion of others, and integrate technological resources to engage in new forms of communication and expression.[34]

Implications for Policy, Leadership, or Practice

Work is well underway across the world to develop policies to encourage deeper learning approaches in schools. In order for students to live successful and productive lives, US education policy developed Next Generation Science Standards, which promote a dual focus on academic learning and real-world application, opening the door for increased experimentation with deeper learning.[35] Deeper learning approaches are also seen as ways to overcome some of the challenges students around the world are facing. A partnership between the British Council and Microsoft is working to address the lack of intellectual engagement in school, rising cost of education, and limited pathways from schools to the workforce through a series of national

level policy engagement seminars in the Association of Southeast Asian Nations countries. These briefings are intended to show how collaboration can support the development of deeper learning policies across the region.[36]

School leaders are working together to create professional development opportunities for teachers so they can more effectively integrate deeper learning in their classrooms. In partnership with Digital Promise, *Getting Smart* released the publication "Preparing Teachers for Deeper Learning" to help teachers respond to how schools and districts are currently redefining K-12 goals. The paper outlines the attributes of the next generation of teachers and provides recommendations on teacher preparation and development systems to shape deeper learning competencies.[37] Another resource for educators is the planning guide based on the book *Deeper Learning: How Eight Public Schools are Transforming Education in the 21st Century*. It offers practical guidance on key strategies to ensure students develop deeper learning outcomes and provides a series of exercises and set of resources for developing a strategic plan to transform schools.[38]

Innovative approaches to using technology for deeper learning are materializing globally, transforming traditional paradigms. Fontan Relational Education (FRE) is a pedagogical model used by public and private schools around the world to train students to become autonomous learners. Through FRE, students are assessed on their knowledge, interests, and abilities and given a personalized plan where students move from one topic to the next only after they are able to relate everything they learned to their daily lives.[39] Students use a cloud-based platform called Qino to keep track of their assessments, learning plans, work, and other indicators.[40] In Florida, middle school students at the Foundation Academy seek answers to central questions or engage in solving real-world problems. Student projects have involved creating presentations, videos, or illustrations that address larger societal problems such as healthy eating, deadly diseases, and water shortages.[41] The goal for these types of experiences is for students to learn by doing, and for them to understand that they can effect positive change on the world — even as students.[42]

For Further Reading

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

NCTAF Learning Studios – Toolkit
go.nmc.org/nctaf
(NCTAF, accessed 7 April 2015.) The National Commission on Teaching & America's Future designed a toolkit to support educators in improving project-based curriculum design to provide student-centered learning opportunities. > *Policy*

Skills for Success: Supporting and Assessing Key Habits, Mindsets, and Skills in PreK-12
go.nmc.org/sfs
(Melissa Tooley and Laura Bornfreund, *New America*, November 2014.) This report highlights habits, mindsets, and non-technical skills that are integral to academic and professional success. It discusses how to effectively cultivate and assess these areas to inform policy. > *Policy*

The Shape of Deeper Learning: Strategies, Structures, and Cultures in Deeper Learning Network High Schools (1 of 3)
go.nmc.org/struct
(Mette Huberman et al., American Institute for Research, 15 September 2014.) This is the first in a series of three research reports on the strategies, opportunities, and outcomes of a set of high schools explicitly organized to promote deeper learning. > *Leadership*

Students at the Center: Deeper Learning Research Series
go.nmc.org/atcenter
(Peter Levin and Kei Kawashima-Ginsberg, *Jobs for the Future*, February 2015.) Deeper civic education can prepare students for success in work and life as well as for active citizenship. This report is part of a new series of William and Flora Hewlett Foundation-commissioned reports which aims to describe best practices in US high schools. > *Leadership*

7 Ways to Hack Your Classroom to Include Student Choice
go.nmc.org/tohack
(Amanda Ronan, *Edudemic*, 20 March 2015.) Students who feel a sense of control over their learning are happier and experience lower levels of stress and anxiety. These suggestions can help educators create an environment that promotes lifelong learning habits so students will feel empowered by their curiosity. > *Practice*

Envision Education
go.nmc.org/env
(Envision Education, accessed 31 March 2015.) Envision School's curriculum and model is based around their "know, do, reflect" approach that helps students excel at the 21st century skills: thinking critically, collaborating productively, communicating clearly, and managing projects effectively, along with several core competencies. > *Practice*

Increasing Use of Collaborative Learning Approaches

Mid-Term Impact Trend: Driving Ed Tech adoption in K-12 education for three to five years

Collaborative learning, which refers to students or teachers working together in peer-to-peer or group activities, is based on the perspective that learning is a social construct. The approach involves activities that are generally focused around four principles: placing the learner at the center, emphasizing interaction and doing, working in groups, and developing solutions to real-world problems.[43] Collaborative learning models are proving successful in improving student engagement and achievement, especially for disadvantaged students. Teachers also benefit through peer groups as they engage in professional development and interdisciplinary teaching opportunities.[44] An added dimension to this trend is an increasing focus on online global collaboration where contemporary digital tools are used to engage with others around the world to support curricular objectives and intercultural understanding.[45]

Overview

Interest in collaborative learning, also commonly referred to as cooperative learning, has been growing rapidly over the past several years. Research is demonstrating how it can be used to promote achievements in reading and writing, conceptual development in science, problem-solving in mathematics, and higher level thinking and reasoning.[46] The report "Exploring Effective Pedagogy in Primary Schools" investigates how successful education systems achieved their results and found that students in exemplary schools spent relatively more time on collaborative learning approaches than those in poor-ranking schools. These higher performing schools implemented pedagogical strategies that included the use of group work for specific collaborative purposes and for peer tutoring.[47] According to the National Education Association, cooperative learning also engages active learning because each student is given the opportunity to contribute in a group setting while claiming ownership of the material.[48]

Through the proliferation of online and mobile tools, it is increasingly possible for students to enhance their collaboration skills anytime and anywhere. According to the "Cloud 401 Report," 35% of IT services today are delivered completely or partially by cloud, providing an infrastructure that supports collaborative activities.[49] The project management software ProofHub,[50] mind-mapping software MindMeister,[51] and Skype[52] are just a few of the myriad applications being used in schools to promote teamwork and peer-to-peer learning. While there is no shortage of resources available, some leaders recommend that schools start by developing proper strategies for learning activities such as clearly defining expectations and instructions, keeping groups small, and closely monitoring and supporting learners.[53]

Collaborative learning approaches are also seen as a way to increase global collaboration, where geographically dispersed educators, classrooms, schools, and other learning spaces use online technologies to learn with others beyond their immediate environment.[54] Leaders in the field suggest a number of related teaching strategies, including building personal learning networks, finding reliable partners, learning curricular standards and frameworks, and redesigning and pre-planning curricula.[55] Additionally, teachers are increasingly using social media to share student voices as well as their own perspectives on various global issues.[56] The key to these approaches is redefining the roles of students and teachers in the classroom so that they become more connected to concerns outside of the classroom.[57]

Implications for Policy, Leadership, or Practice

Although experiments with collaborative learning are growing, there are few policies governing or mandating approaches at the federal and state levels. This model is often wrapped into larger governmental efforts such as Europe's Digital Competence Framework, which contains five competency areas that include advancing collaboration through digital tools and bolstering participation across best practice communities and networks.[58] Leaders in the field suggest that in order to make collaboration more ingrained in schools, policymakers need to rethink how they invest in and organize schools so that there is more time for professional learning and collaboration among teachers.[59] There is still room for effective government policies that incentivize educational collaboratives to identify, create, and disseminate effective practice information and support ongoing training opportunities.[60]

It is becoming clear that teachers need specific skills for establishing collaborative partnerships with peers and other professionals outside of schools.[61] An ITL Research project that involved the participation of eight countries from Finland to Indonesia established strong evidence that innovative teaching occurs more often in environments where teachers receive support from other educators.[62] Many resources are readily available to help teachers acquire these skills. The Stanford Center for Opportunity Policy in Education[63] and Asia Education Foundation[64] are just two groups providing guidance to school leaders and practitioners through toolkits. For professional development, the Teaching Channel[65] is a video-enabled collaboration platform that teachers can use to improve their practice, while the Association for Supervision and Curriculum Development[66] provides Educator Effectiveness Institutes that build capacity for implementing collaborative approaches.

Schools around the globe are engaging in collaborative learning projects that leverage technology to connect teachers and students. For years, New South Wales Public Schools have utilized Microsoft Office 365 and Google Apps for Education for team projects.[67] With BYOD expanding in schools, the new Google Classroom mobile app allows for collaboration anywhere.[68] Engagement with e-books also continues to rise, especially in the United States where 66% of schools offered them in 2014 — up 12% from 2013.[69] At Avenues: The World School in New York, global collaboration through the creation of electronic publications is an important part of their curriculum. Their Global Book series, developed with the Book Creator tool, are e-books authored by educators and students from around the world. Using Twitter as the means of finding contributors, they have published three books aimed at students.[70]

For Further Reading

The following resources are recommended for those who wish to learn more about the increasing use of collaborative learning approaches:

Shelby County School 2015 Technology Plan
go.nmc.org/shelby
(Shelby County Schools, accessed 14 April 2015.) Shelby County Schools created strategies to help students develop specific 21st century skills, including global and cultural awareness and communication and collaboration. They incorporate the National Education Technology Plan's "Model of Learning Powered by Technology," which demonstrates how the classroom can be digitally expanded and connected to the outside environment. > *Policy*

Gamingspace
go.nmc.org/gamspa
(Learning @ NIST, accessed 15 April 2015.) NIST International School is creating a Gamingspace to provide learners with a digital environment that fosters collaboration, problem-solving, communication, risk taking, and play. > *Leadership*

iEARN
go.nmc.org/iearn
(iEARN, accessed 15 April 2015.) iEARN is a nonprofit organization comprised of over 30,000 schools and youth organizations in more than 140 countries that connects educators and young people worldwide through communications technology and collaborative projects. > *Leadership*

Live From Small Town America: Teachers Who Blog To Stay In Touch
go.nmc.org/livefro
(Jasmine Garsd, NPR, 31 March 2015.) Through blogging, teachers in rural or remote areas have created communities that enable them to share best practices and support each other through some of the issues that are specific to smaller schools. > *Leadership*

NAIS Challenge 20/20
go.nmc.org/nais
(NAIS, 4 March 2014.) The National Association of International Schools' Challenge 20/20 Project pairs schools in different countries according to common interests in global problems. Students then work together to study and propose solutions for their chosen problem. > *Leadership*

The Next Big Thing You Missed: A Social Network That Could Truly Reform Our Schools
go.nmc.org/ednet
(Ryan Tate, *Wired*, 17 June 2014.) The author highlights Edmodo, an educational social network with 35 million users, which allows teachers, students, and parents to communicate and share content and helps teachers to expand their personal learning networks. > *Practice*

Ten Ways to Use Discussion Forums to Promote Digital Citizenship and Academics
go.nmc.org/blue
(Michael Gorman, *K-12 Blueprint*, 1 July 2014.) This article gives ten examples of how online discussion forums can expand the classroom walls, allowing students to learn to connect with their community, country, and world. > *Practice*

Shift from Students as Consumers to Creators

Mid-Term Impact Trend: Driving Ed Tech adoption in K-12 education for three to five years

A shift is taking place in schools all over the world as learners are exploring subject matter through the act of creation rather than the consumption of content. A vast array of digital tools are available to support this transformation in K-12 education; indeed, the growing accessibility of mobile technologies is giving rise to a whole new level of comfort with producing media and prototypes. This may be due in part to the rising popularity of social media apps, such as SnapChat, Instagram, and Vine, in which people tell and tag their informal stories through photos and video snippets. Many educators believe that honing these skills in learners can lead to deeply engaging learning experiences in which students become the authorities on subjects through investigation, storytelling, and production. Other components of this trend include game development and making, and access to programming instruction that nurtures learners as inventors and entrepreneurs. As students become more active producers and publishers of educational resources, intellectual property issues will become a key component of K-12 curricula.

Overview

There is growing support for empowering learners as creators that demonstrate their mastery in forms that surpass traditional tests and worksheets. Emerging instructional frameworks are encouraging teachers to use digital tools that foster creativity along with production skills. This trend also implies that educators are increasingly becoming creators, too, and are therefore in the position to lead activities that involve developing and publishing educational content. Apps such as Educreations have helped teachers streamline the process of creating, editing, and publishing video tutorials using a mobile device, while Apple's iTunes U offers a way for teachers to develop digital lesson plans that incorporate their own videos.[71] As teachers become more comfortable using media, they can offer better guidance to their students.

Online screen capture software and web-based tools are enabling teachers and students to create educational videos with minimal equipment and post-production. At Lincoln Middle School in California, a sixth-grade math teacher developed a website called Mathtrain.tv to host student-generated tutorials designed to teach other middle school students. Students use Camtasia Studio to create their mathcasts, which can then be rated and commented on by other users.[72] All videos are shared freely under a Creative Commons license. Additionally, teachers are sharing their instructional videos via TeacherTube, a free online community that provides a safe and dedicated place for educational content. With over 1.5 million users, TeacherTube community members curate content based on appropriateness, subject, and learning standards.[73]

In recent years, games and game development have proven to be a viable means of engaging learners in creation and play at the same time. The popularity of Minecraft, often described as a digital sandbox, is rooted in the simplicity of its premise — players mine resources in order to erect structures in a virtual world. Many schools have already integrated MinecraftEdu into their classrooms, using the interactivity of the game to facilitate experiential learning.[74] Game development in classrooms is also becoming more commonplace as resources such as Scratch, Gamemaker, and Gamestar Mechanic are helping teachers engage learners in design thinking, systems thinking, and project-based learning.[75] A recent survey of 107 game developers and 300 middle school students highlighted the values inherent in game design, including grit, determination, and logical reasoning.[76]

Implications for Policy, Leadership, or Practice

Advocacy movements and major discussions are influencing the way school districts approach copyright policy for teacher and student work. Don't Copyright Me, a project of the Center for Rights, aims to inform stakeholders about the problems associated with district-wide policies that protect all content produced by schools from fair use. The project highlights how schools that copyright student creations unfairly take ownership of their creative works. Students are consequently prohibited to publish, share, and remix their own content in the future.[77] An information policy analyst in the American Library Association's Office for Information Technology Policy recently focused on the importance of understanding copyright and fair use as 3D printers become more commonplace in schools. Schools

need to educate themselves on legal risks as learners become accustomed to using this new technology, namely if they are reproducing and distributing items protected by copyright or patents. School librarians are being encouraged to develop acceptable use policies to protect student creations.[78]

Some schools and organizations are addressing this shift by offering teacher training. For example, the Bloomfield Hills School District in Michigan coordinated a workshop for K-12 educators focused on digital tools and pedagogies that support media production and sharing among students. A video of the session is available on the district's media website.[79] Additionally, Common Sense Media provides teachers with free media resources and toolkits for teaching digital literacy and digital citizenship to ensure that students are aware of the impact of sharing their creations worldwide. As part of their curriculum for grades six and up, the topic of a creator's rights and responsibilities is explored in-depth, beginning with an overview of copyright and fair use, progressing on to the legal and ethical dimensions of creative work, and culminating in a unit on how to remix works while respecting the original creator.[80]

In the classroom, educators are observing that the act of creating videos and media can clarify complex subjects, such as organic chemistry. At ChemEd Ireland 2014, a professional meeting for Irish teachers and faculty, presenters shared how filmmaking and stop motion animation help learners understand chemistry concepts. In the activity, students collaborate on a storyboard that displays the sequence for ionic bonding, chlorination of methane, and catalytic converters. Afterward, students create props using modeling clay or molecular models, and take photographs of the sequence which are uploaded into Windows Movie Maker. Students generated a product that could be critiqued and built upon, and ultimately were able to explain complex concepts to one another.[81]

For Further Reading

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

10 Must Have Resources to Teach about Copyright and Fair Use
go.nmc.org/copyr
(Educational Technology and Mobile Learning, accessed 13 April 2015.) This list of resources can aid educators and students in understanding copyright policies and digital citizenship as it pertains to their own and other creative works in the digital space. > *Policy*

Multichannel Teaching Integrated
go.nmc.org/multich
(Alberto Pian, *DidaNext*, 17 December 2014.) An educator in Italy teaches his students to create their own lessons and produce learning objects with iPads and a variety of applications and resources freely available to them. Students collect their content in the Notability or Evernote apps and collaborate with him and other students to create, discuss, and correct their lesson until it is ready for them to present to the class. > *Leadership*

Program Helps Kansas City-Area Students Create Technology, Not Just Use It
go.nmc.org/kans
(Kyle Palmer, KCUR, 17 October 2014.) Summit Technology Academy offers advanced computer programming courses to students from schools around Jackson County. Most of their class time is spent working in small teams, developing fully functioning software programs based on several coding languages. Last year, students helped the Lee's Summit Historical Society start building a mobile app for its museum. > *Leadership*

The Benefits of Students Teaching Students Through Online Video
go.nmc.org/stuteac
(Katrina Schwartz, *MindShift*, 3 November 2014.) A California middle school teacher found that students are inspired to do some of their best work when they get to choose the topic, show creative license, and publish their own video tutorials online. > *Practice*

Students As Creators: How To Drive Your Students To Be More Than Just Consumers
go.nmc.org/bemore
(Saga Briggs, *informEd*, 20 September 2014.) This article describes how creativity is becoming widely regarded as a vital component of economic growth because the qualities associated with creativity and ingenuity are needed at all levels in both the private and public sectors. > *Practice*

Student-Created App to Guide Shoppers around Downtown Summerlin
go.nmc.org/toguide
(Jan Hogan, *Las Vegas Review-Journal*, 19 May 2015.) A West Career & Technical Academy student proposed the idea of creating an interactive mobile map of downtown Summerlin for his marketing class. The project entailed meeting with local businesses to incorporate their needs in the app and working with Google representatives to build it. > *Practice*

Increasing Use of Blended Learning

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

Perceptions of online learning are becoming increasingly favorable as more schools experience the benefits of blended learning models.[82] Drawing from best practices in online and face-to-face methods, hybrid learning is on the rise in K-12 schools, and a growing number of well-funded initiatives and studies are solidifying the impact of this trend. Schools that embrace blended and hybrid learning models are finding that online learning environments offer different but complementary functions to physical institutions, and can potentially be used to free up class time for activities that make the most from face-to-face interactions in the same space. Additionally, these emerging models support personalized learning, resulting in more engaged, self-directed students. When designed and implemented effectively, hybrid models allow students to practice and achieve mastery of content at their own pace via online learning modules and adaptive software. Teachers are then freed up to focus on small groups of students who need more support to succeed. Progress in learning analytics, adaptive learning, and a combination of cutting-edge digital platforms will continue to advance this trend toward integrated online learning and keep it compelling.

Overview

Blended learning pertains to the formal integration of online delivery for content and instruction; this model combines online work with classroom practice to create a system in which students have greater control of time, pace, and path of instruction.[83] In many cases, blended learning paves the way for other approaches — including competency-based models — that enable personalized learning, promote skill mastery, and inform new roles and responsibilities for teachers. The last scenario is exemplified in USC Hybrid High School (HHS), a charter school in Los Angeles where online learning is the basis of instruction. In its second year, HHS has leveraged a blended learning model to promote teacher autonomy by allocating stipends for them to choose their own software according to their preference.[84]

There is an emerging body of research supporting the viability and effectiveness of this model. The Michael & Susan Dell Foundation recently published the "Blended Learning Report," which summarized the outcomes of a two-year study conducted among twelve K-10 schools serving low-income families. Although many schools faced technical issues in the first year of implementation, the benefits of the new model became clear; the environments allowed teachers to personalize learning and made it easier to facilitate small group instruction for students who needed additional support. Furthermore, teachers reported that their students were endowed with a sense of accountability and ownership over their learning process, and this self-directed culture was crucial to reaping the benefits of online learning.[85]

Blended learning is also being integrated into innovative teacher education programs. A recent whitepaper from the Christensen Institute highlighted three efforts by high-performing charter schools that aim to provide a means of obligatory credentialing while giving teachers an efficient and cost effective way to improve their practice. Founded by a group of notable K-12 education leaders, the Relay Graduate School of Education offers a Master of Arts in Teaching that incorporates a blended learning model where 40% of instruction is delivered online and 60% takes place face-to-face. Student teachers work through competency-based modules, which they can skip or revisit depending on their level of mastery. An online video library supports their learning, allowing teachers to see videos that model best practices in real classrooms. In its instructional and business practices, Relay serves as an exemplar for affordable teacher education that can be scaled.[86]

Implications for Policy, Leadership, or Practice

There are a number of advocacy and policy efforts underway to support the uptake of blended learning designs in schools. The International Association for K-12 Online Learning (iNACOL)'s Center for Policy Advocacy has been providing research on model policies, assessments of the barriers to digital learning, and targeted recommendations that help states implement student-centered learning to scale.[87] iNACOL's latest brief focuses on five critical areas that state policymakers need to know in order to transform K-12 education. The actionable items include creating competency-based education systems; improving student access and equity; measuring and assuring quality from inputs to outcomes; supporting innovative educators; and

supporting new learning models through connectivity, data systems, and security. iNACOL aims to clear the hurdles for states that want to close the achievement gap, prepare students for higher learning or careers, and work toward equity in the education system.[88]

Hybrid learning reflects the reality of a world where work and productivity happen in both physical and virtual settings. An initiative by European Schoolnet is formalizing visions of how technology and new models of learning will impact the design of the classroom, to reflect the new paradigm of education and work. "The Future Classroom Lab" envisions six learning spaces that are designed to optimize physical space, leverage ICT resources, and take into account the transformation of the student-teacher role and dynamic as well as self-directed learning for students.[89] The "Develop" scheme is the most informal layout provided, and it is based on the idea that independent learning is expected to take place at home, while the classroom is used for projects and collaborative activities.[90] In an environment that is homelike and relaxed, learners can exercise their autonomy as they access online resources in study corners and comfortable places.

The blended learning model implemented by SPARK Schools network is the first of its kind in African primary schools. The school day is divided between teacher-led instruction and personalized, online learning enabled by adaptive software. The model features a Learning Lab rotation model where students spend 90 minutes per day immersed in math and language arts, and receive assistance from tutors. There is also 20 minutes allocated during the lab for small group or one-on-one work. The SPARK Schools system proved its impact early on; one year after the launch of its first school, nearly 100% of its 150 students jumped 1.5 grades in reading and scored better than 65% of the country's third graders.[91] This was a revelation considering that when they started, only seven second graders of one hundred were able to read at a kindergarten level.[92] There are currently five SPARK Schools, and the company intends to continue expanding its offering of affordable private education to encompass 60 schools by 2020.[93]

For Further Reading

The following resources are recommended for those who wish to learn more about the increasing use of blended learning:

Digital Learning Now
go.nmc.org/dln
(Digital Learning Now, accessed 20 May 2015.) Digital Learning Now, a national initiative of the Foundation for Excellence in Education, creates an annual Digital Learning Report Card to measure state policies on digital learning based on their alignment to the ten Elements of High-Quality Digital Learning. > *Policy*

Keeping Pace with K-12 Digital Learning
go.nmc.org/pace
(John Watson et al., *Keeping Pace with K-12 Digital Learning*, 2014.) This report describes how policies that exist at the state level influence the extent to which digital learning is available to students. > *Policy*

In Spring City, Pa., Hybrid Learning Sends Test Scores Soaring
go.nmc.org/springcity
(Kathy Boccella, *The Philadelphia Inquirer*, 9 February 2015). Faced with the possibility of closure due to poor performance, administrators at Spring City Elementary persuaded their district to invest in technology and piloted a blended learning approach of digital learning interspersed with small-group instruction. Following a difficult building year, test scores skyrocketed.
> *Leadership*

Blended Learning Revolution: Tech Meets Tradition in the Classroom
go.nmc.org/blendrev
(Amanda Paulson, *CS Monitor*, 20 April 2014.) This article describes how California charter schools including Rocketship Si Se Puede Academy, Edna Brewer Middle School, and Summit network schools are each using different models of blended learning. > *Practice*

Career Path High
go.nmc.org/carpath
(Career Path High, accessed 19 May 2015.) In partnership with Davis Applied Technology College, Career Path High in Utah is a charter high school that employs a blended learning model to give students flexibility and includes internships and hands-on training. > *Practice*

In 'Flipped Classrooms,' Teachers Lecture Online, Use Class for Practice
go.nmc.org/flipfla
(Jeffrey S. Solochek, *Tampa Bay Times*, 22 February 2015.) Florida's Pinellas County School District has found it beneficial to take a more gradual approach to incorporating blended learning concepts, recognizing that initial professional development is vital when it comes to the adoption of innovative strategies. > *Practice*

Online Course Use in Iowa and Wisconsin Public High Schools: The Results of Two Statewide Surveys
go.nmc.org/onlineuse
(Institute of Education Sciences, January 2015.) This study analyzes data from a survey developed to describe how and why brick-and-mortar public high schools in Iowa and Wisconsin leverage online learning. > *Practice*

Rise of STEAM Learning

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

In recent years, there has been a growing emphasis on developing stronger science, technology, engineering, and mathematics (STEM) curriculum and programs, as these disciplines are widely viewed as the means to boost innovation and bolster national economies.[94] As a response to the focus on STEM learning at school and district levels, some education leaders believe there is the need for a more balanced curriculum that integrates disciplines such as the arts, design, and humanities into the sciences. This notion has fostered the STEAM learning movement, in which the A stands for "art+."[95] The company STEAM Education expands this definition to a fundamental philosophy that all disciplines can and should relate to each other to provide students with the big picture of how a wide variety of knowledge and skill sets tie into each other in the real world.[96] In other words, technology use does not exclusively relate to advancing science and engineering; STEAM education is about engaging students in a multi- and interdisciplinary learning context that values the humanities and artistic activities, while breaking down barriers that have traditionally existed between different classes and subjects.

Overview

This trend reflects a shift in how school disciplines are being viewed; schools are converging subjects that have traditionally been isolated from each other — science, mathematics, and art — in favor of deeper, interdisciplinary learning. K-12 education leaders are pioneering new methods for integrating the arts into STEM activities, simulating the ways in which subjects naturally connect in the real world.[97] While this new movement is being discussed almost explicitly in an education context, its roots are embedded across nearly every industry. In many ways, technology is the connective tissue. Popular film, for example, embodies the end goal of successful STEAM practices, combining sophisticated machinery, artistic ability, and precise calculation for effective cinematography. Similarly, engineering new transportation technologies requires artful design. The growing recognition of the important unions between different skills is paving the way for STEAM in schools.

Some skeptics of this movement have dismissed the approach as a mere fad driven by artists who are concerned their profession is losing critical support in an increasingly technology-focused society.[98] However, the Hilburn Academy in North Carolina asserts that STEAM is not just a fleeting program of learning, but an important life philosophy — essential for higher education and career success. Schools should provide students abundant opportunities to appreciate the complexities and sophisticated layers that comprise content knowledge.[99] Early examples of STEAM learning include teaching students how mathematical concepts such as geometry are embedded in artworks and mosaics.[100] Prompting students to design structures with household objects and commonplace technologies has also proven to be a creative exercise in project-based engineering.[101] One chemistry student has even demonstrated an understanding of science by creating moody ink art.[102]

While the rise of STEAM learning is relatively new, there are already statistics that prove that the integration of these seemingly distinct disciplines is bolstering student performance at school. A study conducted by the University of Florida revealed that students who are engaged in music class do better in math. For example, female high school students enrolled in a music appreciation class scored 42 points higher on the math section of their SATs. Students enrolled in four-year music and art programs performed 98 points better than those who had only participated for six months or less. Formal experience with the arts is proven to foster innovative thinking, adaptability, and other problem-solving skills that are essential for mastering STEM competencies.[103] In other words, creativity is a precursor for students to understand, use, and apply technologies in new ways.

Implications for Policy, Leadership, or Practice

While governments are crafting STEM education policies in the US[104] and throughout Europe,[105] STEAM learning has not yet received the same level of attention; it is a nascent trend, and policies often require longer periods of time to be fully established. However, progress is evident in the US, where the bipartisan Congressional STEAM Caucus already includes more than 60 members of Congress. The Caucus has hosted events where education experts have given testimonials about the linkage between STEAM fields and the kinds

of breakthrough innovation that stimulate national progress.[106] At the state level, three California counties — Los Angeles, Orange, and San Diego — have partnered under the leadership of a state senator to launch the "Arts and STEM Collaborative for 21st Century Learning" program. The collaborative aims to establish best practices for teaching STEAM education, in addition to developing instructional frameworks for K-12 learning environments.[107]

Continuing to convene school leaders to discuss and publicize the benefits of STEAM learning is key to advancing this trend. In 2014, the National Association for Music Education (NAfME) sponsored the event "Music Education Powers STEAM: The Broader Minded Role of Music in Preparing a 21st Century Workforce" for government and school leaders with the goal of demonstrating how music education cultivates critical thinking, collaboration, innovation, and other key skills seen as critical to US progress in technology. Online portals and networks are also vital to providing schools and teachers with resources to bolster STEAM learning. The Teaching Channel, for example, has curated a collection of videos about integrating technology use into the visual arts. Videos feature concepts such as using stop animation and using virtual arts programs to engage at-risk youth.[108]

In Australia, the Robotics Club offers extracurricular programs to students that leverage STEAM skills.[109] Many of the activities teach children how design skills such as 3D modeling, along with engineering skills like the understanding of simple machines, can lead to the creation of innovative objects and products. The Dixon Educational Learning Academy in Detroit has an afterschool STEAM program where students recently learned about biology by creatively designing DNA models out of common foods.[110] The Youth in Action STEAM program effectively demonstrates how art and technology are not mutually exclusive; students learn how to create media to document important social and health issues.[111]

For Further Reading

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

STEM to STEAM
go.nmc.org/tosteam
(STEM to STEAM, accessed 22 May 2015.) Rhode Island School of Design is a champion of the STEAM movement and seeks to transform research policy to place art and design at the center of STEM, encourage integration of Art and Design in K–20 education, and influence employers to hire artists and designers. > *Policy*

Prime Time STEAM Initiative
go.nmc.org/ptsteam
(Prime Time Palm Beach County, accessed 2 June 2015.) This website offers free resources for education professionals that are looking to incorporate STEAM activities in their schools and classrooms, and answers some of the most common questions. > *Leadership*

STEAM and Ecosystems in 6th Grade Science
go.nmc.org/eco
(Cambridge Public Schools, accessed 22 May 2015.) Cambridge Public Schools uses a virtual environment developed by Harvard University called EcoMUVE, combined with multiple other activities including initial scientific illustrations, Scratch, and MaKeyMaKey, to help students create their own interactive simulations of ecosystems. > *Leadership*

STEM to STEAM: Resource Round-Up
go.nmc.org/stemto
(*Edutopia*, accessed 2 June 2015.) *Edutopia* curates and regularly updates a section of their website devoted to sharing tips on STEAM learning and showcasing real examples taking place at schools. > *Leadership*

STEM vs. STEAM: Do the Arts Belong?
go.nmc.org/artsbel
(Anne Jolly, *Education Week*, 18 November 2014.) This article explains how to expand STEM projects into STEAM projects and seeks to come to a common ground between proponents of STEM and STEAM curriculum. > *Practice*

Three-Way Partnership Brings STEAM Learning to Underserved Youth in San Diego
go.nmc.org/underser
(Scripps Institution of Oceanography UC San Diego, 8 May 2015.) A partnership between UC San Diego Extension, Scripps Institution of Oceanography at UC San Diego, and the Elementary Institute of Science has led to the launch of two programs in video game programming and robotics to be incorporated into schools. > *Practice*

Significant Challenges Impeding Technology Adoption in K-12 Education

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

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

Policy. While all of the identified challenges had policy implications, two specific challenges are driving policy decisions at many schools at the moment. The easiest one to address is creating policies that incorporate technology into teacher training. Government organizations at both the national and local level are already making ample headway. UNESCO Bangkok, for example, launched the "Supporting Competency-Based Teacher Training Reforms to Facilitate ICT-Pedagogy Integration" initiative to support the creation of national standards for teacher education programs.[112]

A more challenging policy area is that once teachers have been successful at integrating new technologies and pedagogies, it is extremely difficult to scale those innovations across entire schools, districts, and countries. In Ireland, the Dublin West Education Center initiated the Digital Schools of Distinction Award, which is an accreditation for schools whose leaders have demonstrated exemplary vision, engaging curriculum, and compelling uses of emerging technology.[113]

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

Leadership. Again, while all the identified challenges have leadership implications that are discussed in the following pages, two pose roadblocks to employing effective vision and leadership. The most solvable is the notion of creating authentic learning opportunities, which involves giving students ample opportunities to experience real-world situations while still in school. This can take the form of apprenticeship programs and immersive environments and simulations — among other experiences. The Republic of Cyprus recently launched a formal series, "Developing Real World Authentic Learning through the Partnership of Schools and Enterprises," for teachers and career counselors to learn how to better infuse authentic learning into their pedagogies and programs.[114]

In the rapidly evolving landscape of technology and pedagogy, schools are being challenged to rethink the roles of teachers. Employing strategies such as the flipped classroom and other hybrid approaches inherently changes the function of teachers during class. The New Teacher Project (TNTP) published the paper "Reimagining Teaching in a Blended Classroom" that calls for pre-service teacher training and teacher evaluation to be re-conceptualized, given the widespread movement toward online learning. Teachers must be prepared to be virtual facilitators as well as to guide project-based learning and discussions in class.[115]

Practice. Each of the six challenges identified by the expert panel presents numerous impediments for advancing teaching and learning in K-12 education, but two in particular are presenting unique obstacles.

The expert panel perceives that personalizing learning is a difficult task that leaders are only just beginning to fully grasp. Catering to each learner by providing customized opportunities and support requires careful implementation. In Kentucky, students in Taylor County School District are receiving personalized learning through a performance-based education environment in which their "Individual Learning Paths" are designed to fit each of their interests and career goals. This approach is carried out through a blended learning model in which students have access to their coursework at all times. The schools have reported that student performance and retention has increased significantly since initiating this program.[116]

Teaching more complex thinking has also been problematic for schools, especially as traditional paradigms call for each subject to be kept distinct in the form of separate classes. Complex thinking requires leveraging multiple skill sets, such as problem-solving and creativity. The expert panel considers this a wicked challenge as there is not yet a common understanding around language and protocol for defining and assessing complex thinking. Integrating coding into classes is being perceived by many as a way to stimulate computational and creating thinking. In Norway, the Kidsakoder project is helping teachers learn how to integrate coding programs in their classrooms that leverage enabling tools such as Scratch and LegoNXT.[117]

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

Creating Authentic Learning Opportunities

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

Authentic learning experiences, especially those that bring students in touch with real-world problems and work situations, are still all too uncommon in schools. The term authentic learning is seen as an umbrella for several important pedagogical strategies that have great potential to immerse learners in environments where they can gain lifelong learning skills; these approaches include vocational training, apprenticeships, simulations, and portfolio-based assessment. Advocates of authentic learning underscore the importance of metacognitive reflection and self-awareness as cornerstones.[118] A number of schools have begun bridging the gap between academic knowledge and concrete applications by establishing relationships with the broader community; through active partnerships with local organizations, learners can experience the future that awaits them outside of school. All of the measures that schools have taken to integrate authentic learning into curricula are to better prepare students for continued education, vocational careers, and global citizenship, in a way that traditional practices too often fail to do.

Overview

Authentic learning prepares students for the skills and knowledge demanded by universities and the workplace.[119] The trend toward deeper learning (covered in detail in the Key Trends section of this report) runs parallel to this challenge because it highlights the movement toward incorporating experiential and hands-on learning opportunities in schools. This challenge is seen as solvable because its dimensions and solutions are well understood. The task for countries, states, districts, and schools is to learn from successful models, which can be adapted, implemented, and scaled. To accomplish this, desired outcomes must be matched with the appropriate strategy. Whether the goal is to improve retention, foster natural passions and interests, or expose learners to real work situations, authentic learning strategies bring students a greater understanding of their abilities and purpose in life beyond the classroom.

One commonly seen approach to creating this connection is through the development of partnerships with local businesses, organizations, and public entities in the community. Peekskill Middle School students in New York, for example, are working with city representatives on a plan to restore a local park as part of the annual Wheelabrator Symposium for Environment and Education. Students will be conducting a study of Lake Mitchell and looking at water quality, variations in pH, temperature, dissolved oxygen, and other factors to determine what cause an excessive growth of algae. Meanwhile, learners will also be physically clearing trails through the park to help maintain it for public enjoyment.[120] Through this project, students are gaining key STEM skills that form the foundational knowledge of practicing scientists and technicians. This experience of science in action may, for some students, shed light on their future career paths.

The apprenticeship, a historical model that has faded over time, is resurging as more schools see the value in creating vocational opportunities for students. Apprenticeships also have many benefits for businesses as they improve employee retention, save money on wages, and make positive returns on investment.[121] The After School Corporation, a nonprofit organization focused on afterschool programming for schools in New York, created the ExpandEd program to be the intermediary between local organizations and surrounding high schools. Students work on their apprenticeship before or after school throughout the year, which extends into paid summer internships in areas including art, coaching, filmmaking, lifeguarding, and engineering. Every student who participates in the ExpandEd program receives academic credit that counts toward their diploma, adding another incentive that encourages them to stay in school.[122]

Implications for Policy, Leadership, or Practice

While educators are gradually embracing the concept of authentic learning, there is a need for more concrete policies that stimulate the interest of schools and help guide them throughout the process. This includes standards for accrediting authentic learning providers and establishing safety protocol for offsite learning experiences. Current examples of authentic learning often involve initial vocational education, in which high school students are undertaking apprenticeships and shadowing professionals at local enterprises. The

European Commission's report, "Work-Based Learning in Europe," assesses the state of these programs and makes education and labor market policy recommendations to maximize their safety and effectiveness.[123] Among other suggestions, the report calls for investing in other types of work-based learning, such as the development of onsite labs and workshops in schools that link back to the offsite vocational training.

In order to facilitate authentic learning in their classrooms, school leaders need to be aware of what models, training strategies, and resources exist to support this approach. A recent project by the Republic of Cyprus produced a formal series of teacher training seminars on the topic of "Developing Real World Authentic Learning through the Partnership of Schools and Enterprises." Aimed at teachers and career counselors, the teacher education program leverages an online learning environment to facilitate 20 hours of training in theoretical and practical components of implementing authentic learning models.[124] In Utah, the Park City School District created a program with the Center for Advanced Professional Studies which partners local professional mentors with students to work on projects in business, engineering, interactive design, teaching, and technology. Now serving more than 2,000 students annually, many learners have reported that the program has helped them find their passion, which has then informed their choices when applying to universities.[125]

Portfolios have been proven to empower students to take ownership of their studies and to develop key lifelong learning skills such as critical-thinking, reflection, and problem-solving.[126] At the 13th Primary School of Drama in Greece, eight-year-olds are learning Greek through the use of e-portfolios, which require the young students to compose personal reflections after each activity on Google Drive. According to a case study on this environment, parents related that the e-portfolios improved their child's ability to articulate their thoughts and narrate their learning process, while teachers reported increased student engagement.[127] Middle and high school students from the American School of São Paulo recently showcased their e-portfolios at the Innovate 2015 conference. The annotated student blogs included explanations of activities, adjustments in learning strategy, learning artifacts, conclusions, and further questions, and covered topics such as "An Energy Proposal for China" and "The Power of Ruling People," among others.[128]

For Further Reading

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

Building a Tech Culture
go.nmc.org/cultu
(Bill Hangley Jr., *The Notebook*, 25 March 2015.) The Philadelphia School District's latest Action Plan avoids defining a baseline technical standard for all schools or calling for a district-wide boost in capacity. This article describes the importance of school culture, backed by district culture, to allow educators and students the freedom to experiment and innovate in a technology-enabled environment. > *Policy*

Authentic Assessment Toolbox
go.nmc.org/authas
(Phil Nast, National Education Association, accessed 13 April 2015.) An important aspect of promoting authentic learning is creating accompanying assessments for students when they perform real-world tasks to demonstrate subject mastery. This toolbox is a resource to help educators create activities, rubrics, and standards for measuring and improving student learning.
> *Leadership*

Idaho Teen GameLab
go.nmc.org/idahoteen
(Idaho Teen GameLab, accessed 16 April 2015.) Idaho Teen GameLab is a six-week, online academic camp that leverages 3D GameLab to provide career and college exploration opportunities in the field of digital game design. > *Leadership*

Students Aren't Waiting to Improve Their World
go.nmc.org/theirworld
(Suzie Boss, *Edutopia*, 24 March 2015.) At the Global Social Entrepreneurship Summit at the American School of Bombay in India, more than 70 students convened for a two-day immersion in social problem-solving.
> *Leadership*

Authentic Data, Authentic Learning! Part 1: NASA Data on Wavelength
go.nmc.org/wavele
(Andrew Clark, NASA Wavelength, accessed 13 April 2015.) NASA has made freely available troves of scientific data gathered by peering into deep space and sampling Earth's atmosphere. Integrating this authentic data can help keep lessons current and connected to the world outside the classroom. > *Practice*

Culminations at Nueva
go.nmc.org/culm
(*Nueva Now*, 11 December 2014.) In an effort to provide a more authentic manner of measuring student progress, the Nueva School's culminations, which take the format of interactive presentations, specific projects, and performances, provide students the opportunity to share the knowledge they have gained at the end of each semester with the broader community. > *Policy*

Integrating Technology in Teacher Education

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

Teacher 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. Despite the widespread agreement on the importance of digital competence, training in the digital-supported teaching methods is still too uncommon in teacher education and in the preparation of teachers.[129] As teachers begin to realize that they are limiting their students by not helping them to develop and use digital competence skills across the curriculum, the lack of formal training is being offset through professional development or informal learning, but digital media literacy is not yet the 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.

Overview

To prepare learners for a world that increasingly leverages technology, current and future educators need to continually sharpen their skills in the face of shrinking budgets.[130] The lack of adequate teacher education relating to digital skills is a challenge that is widely documented. The report "Educators, Technology, and 21st Century Skills," by Walden University, revealed that the problem often begins at the initial training level; researchers cite that many teachers believe that their pre-service training did not prepare them well in either technology or 21st century skills. Furthermore, on-the-job training often focuses on how to operate equipment without showing how to effectively incorporate it into instruction.[131] Researchers from the Institute for Policy Research at Northwestern University studied obstacles to successful technology integration and found that inadequate training and teachers' attitudes on the educational value of technology have the strongest impact.[132]

In-service teacher training is an area of concern as new technologies are often deployed at schools without sufficiently preparing teachers. Even if a teacher is comfortable with using new digital tools, they may not have help to maintain the devices as some districts have few to no technology support on staff.[133] In a digedu nationwide survey of over 600 teachers in the US, 50% cited inadequate assistance when using technology in the classroom and 46% of teachers reported that they lack the training needed.[134] In Europe, the "Survey of Schools: ICT in Education" also identified several obstacles that are all too often present when implementing ICT (information and communications technologies) in the classroom, ranging from insufficient equipment for digital learning, lack of competence and pedagogical models, and unclear goals for using ICT.[135]

Technology already permeates almost every dimension of life outside of school, and both students and their parents expect schools to help them to become digitally competent. India is projected to contribute 27% of the world's workers between 2010 and 2030, but their quality of digital education is lacking. Inadequate teacher training, significant teacher absenteeism, and poorly trained administrators continue to challenge schools there.[136] Furthermore, the Norwegian SMILE report found that the uneven pedagogical use of technology in the classroom revolves around a number of factors, but the most important finding is that the level of a teacher's digital competence directly correlates with students' learning outcomes when technology is used.[137]

Implications for Policy, Leadership, or Practice

One of the reasons this challenge is perceived as solvable is that it is well understood, and solutions are already available. In the US, the Obama administration's ConnectED program is earnestly investing in improving the skills of teachers through support and training in using educational technology tools for improving student learning.[138] In the Democratic Republic of Congo, similar measures are being taken to improve access and quality of teacher training. Their "Strengthening National Capacity for Training on the Job" program included the development and online publication of educational materials as well as training on how to use new tools and equipment.[139] Lessons learned from ICT in Education projects of UNESCO Bangkok revealed a disconnect between national ICT-in-education policy and effective teacher use of ICT to enhance pedagogy in the Asia Pacific region. In light of these findings UNESCO Bangkok is implementing the "Supporting Competency-Based Teacher Training Reforms to Facilitate ICT-Pedagogy Integration" project to support member states in creating national standards that will align teacher education programs with their policy vision and goals.[140]

University pre-service teacher programs are also increasingly recognizing the importance of technology training, and some are stepping up with new initiatives to mitigate the issue. University of North Carolina-Greensboro's School of Education was recently awarded a five-year grant from the US Department of Education to use technology to recruit, train, and support technology integration across all teaching fields.[141] In Spain, the Universidad Pablo de Olavide developed the "New Information Technologies and Communication" module for teachers of secondary education students. Among the objectives are to develop interactive concept maps about the strengths and weaknesses of ICT in educational contexts and to encourage multimodal learning.[142] Another program in the online learning space is TEACH-NOW, a teacher preparation program where pre-service teachers learn by doing projects together with an instructor. The program is built on four pillars of effective learning: technology, collaboration, practical application, and classroom experience.[143]

Teachers looking to learn more about effective use of technology in the classroom can turn to the growing array of resources aimed precisely at this need. "Edukata," for example, is a participatory design model that enables Finnish in-service teachers to turn their innovative ideas into actual classroom practice.[144] They do so by investigating digital scenarios such as BYOD, the flipped classroom, or online learning, and creating future classroom learning activities that reflect key aspects of the personal interests and needs of their students. Similarly, European Schoolnet's Academy provides free online teacher training in key ICT concepts and ideas and enables practicing teachers to share their experiences with their colleagues across Europe. What began as two pilot courses has now grown to include new courses such as "Games in Schools," "Competences for 21st Century Schools," and "How to Teach Computing."[145]

For Further Reading

The following resources are recommended for those who wish to learn more about integrating technology in teacher education:

How eSafe is Your School?
go.nmc.org/esafety
(eSafetyLabel, accessed 16 April 2015.) European Schoolnet has launched an eSafety Label — a pan-European accreditation and support service for schools to analyze their media literacy status. Once the self-assessment is completed, each school receives an action plan to help school staff and educators address their eSafety infrastructure in areas including cyber-bullying, data protection, copyright and plagiarism, and online behavior. > *Policy*

Minnesota Tech Collaborative Adopts Platform To Provide PD to 49 Districts
go.nmc.org/minne
(Joshua Bolkan, *THE Journal*, 12 March 2015.) TIES, a Minnesota education technology collaborative, partnered with BloomBoard to provide a technology platform that allows educators in its 49 member districts to access TIES-produced webinars and courses online. The platform offers a comprehensive resource library as well as a collaborative space. > *Leadership*

NRICH: Enriching Mathematics
go.nmc.org/nrich
(University of Cambridge, NRICH, accessed 20 May 2015.) NRICH is a team of teachers that offer both online and face-to-face advice and support to mathematics educators as well as a variety of free resources geared toward the development of problem-solving skills and mathematics in meaningful contexts. > *Leadership*

Picademy
go.nmc.org/pica
(The Raspberry Foundation, accessed 15 April 2015.) Picademy is a free two-day professional development experience in Cambridge for primary and secondary teachers. The Foundation's Education Team leads educators through hands-on workshops on how to use Raspberry Pi for a multitude of learning activities.
> *Leadership*

Wikiwijs
go.nmc.org/wij
(Wikiwijs, accessed 16 April 2015.) Wikiwijs is an initiative of the Knowledge Network, the Open University, and SLO that provides a platform where educators can exchange learning materials they have created. It contains a content editor and tools to arrange content blocks into individual lessons or larger components. > *Leadership*

Innovation Configuration for the Use of Technology in the Preparation of Pre-Service Teachers
go.nmc.org/ceedar
(Lisa A. Dieker et al., *Ceedar Center*, October 2014.) This paper provides an innovation configuration matrix that can guide teacher preparation professionals in the development of appropriate use of technology in the preparation of pre-service teachers. For each technology, it lays out a summary of the existing research, clearly defined practices, and considerations for teacher educators to incorporate the practices.
> *Practice*

Personalizing Learning

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

Personalized learning refers to the range of educational programs, learning designs, instructional approaches, and academic-support strategies intended to address the specific learning needs, interests, aspirations, or cultural backgrounds of individual students.[146] While there is a demand for personalized learning, it is not adequately supported by current technology or practices. The increasing focus on student-centered learning is driving the development of new technologies that provide more choice and allow for differentiated instruction. Advances in online learning environments and adaptive learning technologies are making it possible to automate the processes of a learner's individual learning path, although much of the discussion of personalizing learning in K-12 education is focused on redesigning how schools work; that is, emergent solutions to this challenge emphasize competency education, which is a student-centered system that overturns the traditional paradigm. The biggest barrier to personalized learning is in condensing myriad methods and technologies into a streamlined strategy that can be implemented, scaled, and replicated throughout schools.

Overview

The goal of personalized learning is to create possibilities for learners to determine the strategy and pace at which they learn. While enabling technologies such as mobile devices and adaptive learning environments support student-centered learning, this challenge is concerned with the need for schools to overhaul their curricula in favor of designs that emphasize the individual over the one-size-fits-all standard. Competency-based education has been highlighted as a potential solution, and the objectives of this model ensure that students demonstrate mastery of explicit, measureable, and transferable skills. They receive differentiated support based on their individual learning needs, and the learning outcomes are the application and creation of knowledge — in addition to the development of character. In this approach, the assessment of the skills that students gain should be a positive and meaningful experience for students.[147]

While progress has been made toward defining terms, technological tools and emerging models that support personalized learning need greater understanding and evaluation. At Intrinsic Schools in Chicago, students engage in differentiated learning through the use of a Chromebook laptop and ThinkCERCA, a web-based program that guides learners through the steps of writing essays and helps them advance their reading levels. Learners rotate between computer-mediated exercises and teachers-class interaction, a model that is typical in progressive schools.[148] Yet education experts caution that this approach may be indicative of personalized learning solutions being sold to schools as a mass commodity that helps them raise standardized test scores, ultimately missing the goal of making learning a more meaninful experience.[149]

Indeed, the potential for true personalized learning, which is founded on learner autonomy and individualized progress and support, is constrained by the overwhelming pressure put on schools to perform on standardized assessments. Education leaders argue that for as long as the current system is in place, the creativity and innovation afforded by this approach will be stifled by mechanisms of control and compliance.[150] The Education Ministry of British Columbia (BC) recently consulted a top international education researcher to help write the new BC Education Plan.[151] The resulting recommendation was to demolish the Foundation Skills Assessment, the provincial standardized exam, citing that these large-scale uniform processes stifle children's natural talents and passions. As part of the new "K-12 Innovation Strategy," BC's government will partner with educators to determine several schools that will be among the first to be excluded from standardized testing and instead serve as pilot sites for curriculum renovations based on personalized learning.[152]

Implications for Policy, Leadership, or Practice

While scalable methods will take some time to refine, there is considerable consensus among policymakers in some parts of the world about the importance of personalized learning. Finland underwent a substantial policy reform in the 1970s that has fostered an environment in which students can succeed as individuals.[153] One outcome of this shift was that the country's national core curriculum went from a highly centralized system to a localized one, where teachers and administrators define the

educational goals for their school with the national curriculum as a model.[154] As a result, teachers can focus on conducting more formative evaluations that provide meaningful insights into each learner's progress.[155] Similarly, the New Zealand government offers schools autonomy over their teaching and learning activities. Teachers put a tremendous amount of value in students' self-assessments, empowering learners to articulate and become invested in their own achievements.[156]

A number of organizations are prioritizing personalized learning by leading major initiatives. The US Department of Education's Race to the Top program has funded 21 K-12 education projects that have made personalized learning the basis of their visions. A recent report by the District Reform Support Network chronicled the progress with in-depth case studies, along with a list of considerations for implementation including enhancing technology, shifting the teacher's role, and renovating physical spaces.[157] This challenge has also gained attention through the movement behind "next generation learning models" that espouse personalized learning as the ultimate goal. The National Alliance for Public Charter Schools tracked these advances in "Breakthroughs in Time, Talent, and Technology," a 2014 survey of charter schools with fluid learning environments, innovative roles for teachers, and the various administrative autonomies required to implement a learner-centered system.[158]

Personalizing learning can manifest in a variety of school configurations. At Cornwallis Academy in England, every student has a laptop which they use to study in one of many learning plazas — bright open spaces equipped with displays and designated areas for group work. Students have a range of choices for how their productivity unfolds each day, and teachers keep them on track by providing a stream of continuous feedback.[159] Students in Taylor County School District in Kentucky are learning in a "performance-based" education environment in which their "Individual Learning Paths" are designed to fit their interests and career path. Combined with a blended learning approach, students have access to their coursework 24/7. For these reasons, many learners finish their core requirements by the middle of their third year and spend the rest of their time in school earning college credits from the district's partner institutions, or working internships with local enterprises.[160]

For Further Reading

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

A Policy Playbook for Personalized Learning: Ideas for State and Local Policymakers
go.nmc.org/perspol
(Carolyn Chuong and Sara Mead, Bellwether Education Partners, 2014.) Policymakers are one of many groups of stakeholders who must play a role in expanding students' access to personalized learning. This policy playbook is designed to provide policymakers with actionable ideas that can support the growth of high-quality and accountable personalized learning opportunities. > *Policy*

Personalized Learning Roadmap
go.nmc.org/ful
(Fulton County Schools, March 2014.) Fulton County Schools has committed to creating a student-centered culture using personalized instructional strategies. They have created a roadmap outlined in this report based on a synthesis of personalized learning definitions across the landscape nationally. > *Leadership*

What Is 'Personalized Learning'? Educators Seek Clarity
go.nmc.org/clarit
(Sean Cavanagh, *Education Week*, 4 May 2015.) This article describes how education technology companies and organizations are all trying to create a clearer definition of personalized learning. The author underscores that a core aspect of creating a personalized learning environment is the shift of perspective and agency to that of the student rather than the curriculum and educator. > *Leadership*

Choose Your Own Adventure: Canadian History Style
go.nmc.org/choose
(Greenwood College School, *Personalized Learning*, 4 February 2014.) A Canadian history teacher at Greenwood College School developed online materials for a variety of 1920s unit topics to allow his students choice over their focus. > *Practice*

Learning Menu Lets Students Personalize Class Requirements
go.nmc.org/menu
(Charlie Boss, *The Columbus Dispatch*, 20 January 2014.) Several teachers at Hilliard Darby High School are experimenting with learning menus in which students choose assignments from a variety of activities, including video projects, study guides, research projects, and lab work. > *Practice*

The Learning Relationship Management Movement
go.nmc.org/lrm
(Brian Fleming, *Eduventures*, 3 April 2015.) This article describes how a few new companies are disrupting the learning management system market with a more holistic student success solution known as learning relationship management. > *Practice*

Rethinking the Roles of Teachers

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

Teachers are increasingly expected to be adept at a variety of technology-based methods and other approaches for content delivery, learner support, and assessment;[161] to collaborate with other teachers both inside and outside their schools; to routinely use digital strategies in their work with students; to act as guides and mentors to promote student-centered learning; and to organize their own work and comply with administrative documentation and reporting requirements. The integration of technology into everyday life is causing many education thought leaders to argue that schools should be providing ways for students to continue to engage in learning activities, formal and informal, beyond the traditional school day. As this trend gathers steam, many schools across the world are rethinking the primary responsibilities of teachers. Related to these evolving expectations are changes in the ways teachers engage in their own continuing professional development, much of which involves social media and online tools and resources. While fully online schools are still relatively rare, an increasing number of teachers are using more hybrid and experiential learning exercises, and experimenting with social media and other ways of building learning communities.[162]

Overview

As more schools transition to 1:1 and BYOD models,[163] students are spending more time engaging with devices than they are facing the front of a classroom. The use of mobile and other technologies, combined with new instructional approaches and the ubiquity of the Internet, have led to more student-centered learning where students have autonomy over the tools and materials they use. As a result, teachers simply cannot take on the same roles they have traditionally held as lecturers and information dispensers. In ideal situations, the teacher's role is becoming that of a mentor, visiting with groups and individual learners during class to help guide them, while allowing them to have more of a say in their own learning. However, these types of interactions and the enabling use of technology are not always inherent or sufficiently integrated in pre-service training.[164]

A recent study from the Academy of Finland shows how technology-enhanced learning activities have shifted the nature of teaching. Teachers are increasingly expected to be effective facilitators, engaging in joint problem-solving with their students.[165] This cannot be accomplished, however, if teachers are unable to implement emerging digital tools in creative ways. Furthermore, UNESCO's report, "Supporting Competency-Based Teacher Training Reforms to Facilitate ICT-Pedagogy Integration in Uzbekistan," reveals why teachers in Uzbekistan and surrounding areas are not yet using technology in transformative ways.[166] One of the main reasons cited is that while governments have mandated specific tools, teachers have not received sufficient training to integrate them in their curriculum and classrooms effectively. The UNESCO Tashkent Office held a workshop in early 2015 to support ministries of education in defining and developing ICT competencies and training programs for teachers.

As inherent in several trends in this report, including the shift to students as creators, learners are being given more autonomy over how they approach projects and subject matter. This notion further underscores the need for teachers to rethink their pedagogies and curriculum in ways that enable students to customize their own paths. CORE Education, an organization in New Zealand, listed the growth of inclusive design among their top ten trends for 2015.[167] At the heart of this trend is the incorporation of the student voice in virtually any school activity and program. An increasing number of students and teachers are working together to determine the most effective ways to use technology for learning that reflect varied student interests. In this view of the 21st century classroom as depicted by CORE Education, students are not just learning from teachers; teachers are also learning from their students, which requires a spirit of collaboration and flexibility.

Implications for Policy, Leadership, or Practice

Government research and policies have been key thus far in forging solutions to this difficult challenge. The European Commission's "Rethinking Education" framework has prompted programs that incorporate more open educational resources and technology in the classroom,[168] calling attention to the need to rethink the teaching profession and provide ongoing professional development to educators. A Council meeting of the

European Union presented a set of conclusions and policy recommendations that emphasized better initial teacher training and early career support.[169] A related area that will require clear policy is teacher standards and assessment. In the US, the Kentucky Department of Education recently announced the "Kentucky Framework for Teaching," which is aligned with InTASC Model Core Teaching Standards,[170] a constructivist view of teaching and learning. Effective technology integration and the ability to accommodate individual student needs are named among the primary skills that should be evaluated for teachers.[171]

It will take visionary leadership to reimagine instructional approaches and prepare school leaders accordingly. The New Teacher Project (TNTP), an organization that works with schools and districts to diminish education inequality,[172] recently published a paper about how the move to online and blended learning models is challenging traditional functions of teachers.[173] "Reimagining Teaching in a Blended Classroom" points to pre-service teacher training and teacher evaluation as two critical areas that need to be re-conceptualized, based on the prediction that half of US high school students will engage with online learning in some form by 2019.[174] The paper identifies three major roles for the teacher of the future: researcher and developer, integrator, and guide. Responsibilities include designing instructional approaches and materials that reflect student needs, proactively sharing ideas with colleagues, and using data to adjust student pathways. TNTP recommends that teacher education and professional development promote data analysis, risk-taking, and collaboration as core educator competencies.

Many hybrid learning classroom pilots and programs are already well underway. Shelby County School District's 16 schools in Tennessee are embarking on a blended learning pilot with Pearson, which will significantly change the role of teachers. Both students and teachers will have access to a tablet that they are able to use throughout the school day and take home with them. In class, students rotate between computer stations, group work areas, and a teacher-led station. Teachers have access to each student's screen and information during every activity to observe where any struggles are taking place and provide more personalized support along the way.[175] In this instructional model, rather than teachers being the "sage on stage," they manage activities and provide help when needed. Similarly, the New School in Atlanta, Georgia states outwardly in their mission that teachers are guides. They are characterized as demonstrating key values such as patience and accountability while they coach students through projects in small classes.[176]

For Further Reading

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

Redesigning Schools to Extend Excellent Teachers' Reach
go.nmc.org/extend
(Public Impact, accessed 20 May 2015.) Public Impact's Opportunity Culture project seeks to extend the reach of excellent teachers through redesigning their jobs. The organization is advocating for change at the policy level and has developed various teaching models that combine both remote and face-to-face instruction. > *Policy*

The Deconstruction of the K-12 Teacher
go.nmc.org/decon
(Michael Godsey, *The Atlantic*, 25 March 2015.) A veteran teacher examines his evolving role from information gatekeeper, parceling out knowledge, to facilitator and guide, assisting students with accessing shared resources. > *Leadership*

First-Grade Students Using Augmented Reality to Teach Others about Kansas
go.nmc.org/arkids
(Brian Sanders, *The Holton Recorder*, 29 January 2015.) A Kansas elementary school class created an interactive display with augmented reality components. The teachers guided the students to act as leaders on the project. > *Leadership*

Is Learning Increasingly Self-Directed in the Digital Era?
go.nmc.org/increa
(Suren Ramasubbu, *The Huffington Post*, 28 April 2015.) The author cites six important roles a teacher plays in self-directed learning: content resource, resource locator, interest stimulator, positive attitude generator, creativity and critical thinking stimulator, and evaluation stimulator. > *Leadership*

Virtual Learning Program Leads the Tech Front in Palo Alto's Public Schools
go.nmc.org/schoology
(Corey Whelan, *CBS Los Angeles*, 20 March 2015.) Schoology shifts the role of teachers to facilitators that help students connect with other learners around the world to collaborate on assignments and participate in discussions. > *Practice*

What Happens When Students Control Their Own Education?
go.nmc.org/studcent
(Emily Richmond, *The Atlantic*, 24 October 2014.) A New Hampshire school obtained funding to implement a student-centered learning approach. In the classroom, teachers monitor student-led discussions and provide guidance and feedback. > *Practice*

Scaling Teaching Innovations

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

Schools are not yet adept at moving teaching innovations into mainstream practice. Innovation springs from the freedom to try out and implement new ideas, yet schools generally allow for top-down changes that unfold in prescribed ways. Current organizational promotion structures rarely reward innovative approaches and improvements in teaching and learning, much less allow these breakthroughs to be scaled and replicated. As a result, many educators become frustrated by the rigid confines of a school that is in desperate need of transformation. Scaling pedagogical innovation requires the removal of restrictive policies, adequate funding, capable leadership, and strong evaluation practices — a tall order for the majority of K-12 public schools, which are receiving fewer resources.[177] The reality is that many teachers are not prepared to lead innovative, effective practice, and there is a kaleidoscope of systemic factors that must be addressed to resolve this complex issue.[178]

Overview

According to the Brookings Institution, scaling teaching innovations is an especially wicked challenge because it is a matter of absence over presence. They argue that it is not a social problem, but a problem related to infrastructure that was never built to help identify effective practices and systems. National education reforms, such as "Race to the Top" in the US, tend to be implemented broadly without comparison groups in mind to measure efficacy.[179] Solutions, therefore, may come from looking at how the healthcare industry scaled innovation — improvement science was an approach used in the 1980s and 90s that empowered practitioners to identify problems, test improvements, and iterate solutions in a shareable way. Education leaders believe that similar approaches can help schools construct, implement, and share new models.[180]

Funding and adequate training for new teachers are imperative to implementing and scaling new models of teaching. The inquiry-driven, project-based Science Leadership Academy (SLA), a public magnet school in Philadelphia, has recently been replicated at a new SLA campus, but not without overcoming a number of hurdles. In order to scale, the superintendent had to pass a five-year, $28 million plan, which will only fund three of these types of schools in the district. While teachers at SLA are supportive of the new style of teaching for its ability to engage learners on a deeper level, they related that there is a steep learning curve, and the risk of burnout is very high. Experts on the topic surmise that these types of innovations often fail because teachers struggle against the odds; their formal education has not prepared them to implement novel instructional approaches, and strong support systems for effective professional development are scarce.[181]

In the *Social Stanford Innovation Review*, the executive leader of a private health foundation[182] cited that the problem is not the absence of innovation, but a trend that leads agencies — both public and philanthropic — to provide seed funding to new ideas rather than scaling projects and models that already work. As a result, pockets of isolated innovation do not make the kind of broad impact that will effect systemic change at the institutional, social, or political level. The author believes that any effort to scale innovation should be focused on supporting advocacy and organizing communities around existing models, creating a united voice that is heard through social media platforms and other outlets. The difficulty lies in capturing the impact of social movements in a way that funding agencies can digest.[183]

Implications for Policy, Leadership, or Practice

Policies that support innovation in teaching, although still rare, are paving the way for states and districts to implement and scale novel models of instruction. In West Virginia, the Innovation Zones Act allows schools to apply for exemption from policies and codes that inhibit new methods of teaching and learning.[184] As a result of this policy, many schools have been granted control over resources, personnel, curriculum, schedule, technology utilization, and other factors that help them apply or replicate innovative systems.[185] Governments and foundations are developing programs that have the potential to impact schools worldwide. In Georgia, the state government established an Innovation Fund that offers competitive grants to support schools in the planning, implementation, or scaling up of innovative programs across the state. Awardees of Scaling Grants evaluate the effectiveness of their projects and

submit their findings to the state to help inform policy decisions.[186]

Recognizing and supporting schools that have successfully scaled teaching innovations is a crucial part of addressing this challenge. In Ireland, the Dublin West Education Centre partnered with several other local education organizations and technology providers to develop a nationally recognized Digital Schools of Distinction Award — an accreditation system for primary schools who integrate digital technologies in schools in the areas of leadership and vision, the curriculum, school culture, continuing professional development, and resources and infrastructure.[187] The National Center on Scaling Up Effective Schools is a national research and development program that guides schools through individual and organizational capacity-building efforts that are essential to change management.[188] Participating teachers have remarked that the center's ground-up approach is an inclusive, reflective design that helps them consider how improvements can be made at every level of the organization.[189]

Establishing networks of practice is helping school leaders and teachers bring change management to scale. Coordinated by European Schoolnet, Living Schools Lab (LSL) was a two-year initiative that brought together 12 Ministries of Education and 15 partners to form an expansive network of schools focused on peer exchange and scaling up best practices.[190] The key organizing principles of LSL were based on region and stages of progress, which established strong mentoring and collaboration relationships between schools and teachers.[191] The Teach First Innovation Unit is another initiative formed around discovering best practices to solve the problem of educational inequality in the UK. Teachers can get involved with the program at any stage by generating ideas during "innovation weekends," testing their ideas with the help of funding, and scaling their projects through tailored support.[192]

For Further Reading

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

Districts Find New Way to Fund Technology
go.nmc.org/etbonds
(John Fensterwald, *EdSource*, 7 November 2014.) Three school districts have passed a new form of school bonds called EdTech Bonds, aimed at ensuring technology purchases are more affordable and frequent. They are a series of low-interest, short-term bonds designed to create a replacement cycle for equipment after it wears out. > *Policy*

Teach To Lead
go.nmc.org/tolead
(Teach to Lead, accessed 20 May 2015.) Teach to Lead is an initiative jointly convened by the National Board for Professional Teaching Standards and the US Department of Education that seeks to encourage, support, and expand teacher leadership. It has developed the Commit to Lead online platform as a crowdsourcing method where educators share and vote on ideas to inform policy. > *Policy*

The Ellis School (Pittsburgh) Learning Innovation Institute
go.nmc.org/ellis
(Lisa Abel-Palmieri, The Ellis School, 2014.) In 2014, the Ellis School, an all-girls school in Pittsburgh, launched the Learning Innovation Institute, an incubator to test innovative practices such as design thinking, and maker education. The school will also appoint members of its faculty as Innovation Fellows, who will act as consultants and ambassadors to share best practices and improve learning outcomes. > *Leadership*

Innovation Leadership in Schools
go.nmc.org/innolearn
(Lindsey Own, *Getting Smart*, 4 April 2015.) An educator facilitated a digital conversation about scaling innovation in schools during the 2015 SXSWedu conference and used the results to curate a job description for a leadership role to support education innovation. > *Leadership*

The Learning Designer
go.nmc.org/designer
(Building Community Knowledge, accessed 14 May 2015.) The London Knowledge Lab is working on a web-based learning design tool to allow educators to better visualize, create, and reflect on their teaching and learning activities, thus giving them the ability to determine if their design is supporting the types of learning experiences they seek to achieve. The community Learning Designs Challenge and online directory encourage sharing of learning designs between educators and building off ideas of other educators. > *Leadership*

Future Ready: Roadmaps to Tech Integration
go.nmc.org/techmap
(Andrew Marcinek, *Edutopia*, 6 February 2015.) This article posits that a successful technology initiative should begin not with a focus on the device or app, but on identifying classroom leaders and innovators, and trusting those teachers to create pedagogical methods that integrate the new technology to challenge the students. The author also provides suggested planning phases for pilot programs. > *Practice*

Teaching Complex Thinking

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

It is essential for young people both to understand the networked world in which they are growing up and also — through complex thinking — to learn how to use abstraction and decomposition when tackling complex tasks and to deploy heuristic reasoning to complex problems.[193] Mastering modes of complex thinking does not make an impact in isolation; communication skills must also be mastered for complex thinking to be applied meaningfully. Indeed, the most effective leaders are outstanding communicators with a high level of social intelligence; their capacity to connect people with other people, using technologies to collaborate and leveraging data to support their ideas, requires an ability to understand the bigger picture and to make appeals that are based on logic, data, and instinct. While some aspects of this topic could be framed as similar to or overlapping "design thinking," for the purposes of this report, the two are considered as distinct concepts. The term "complex thinking" refers to the ability to understand complexity, a skill that is needed to comprehend how systems work in order to solve problems, and can be used interchangeably with "computational thinking."[194] Teaching coding in schools is increasingly being viewed as a way to instill this kind of thinking in students as it combines deep computer science knowledge with creativity and problem-solving.[195]

Overview

The value of complex thinking is already reflected in Silicon Valley, where coding has long been recognized as a critical literacy that often involves scientists and programmers discerning patterns and communicating through visualizations as a means of solving problems and driving innovation.[196] Computer science requires the best of complex thinking, as the field is no longer just about technical skills, but also the ability to effectively organize and communicate ideas. Code.org projects that by the year 2020, there will be 1.4 million computing jobs but only 400,000 computer science students to fill them. Compounding this challenge is the fact that less than 2.4% of college students graduate with a degree in computer science —numbers have steadily declined in the past decade.[197] As a result, an increasing number of school leaders are making the case that coding needs to be integrated into curriculum at the K-12 level as a means of promoting complex thinking at a young age.[198]

Many schools across the world are already responding to the challenge of teaching complex thinking through the form of coding classes and programs in which students collaboratively design websites, develop educational games and apps, and design solutions to local challenges by modeling and prototyping new products.[199] According to *Edutopia*, coding has a profound impact on complex thinking and is tied to improved problem-solving and analytical reasoning skills. The learning process helps students to "construct, hypothesize, explore, experiment, evaluate, and draw conclusions." Introducing coding to students also serves as an equalizer in that learners with Autism Spectrum Disorders are able to best showcase their innate talents for pattern development and creative technology use.[200]

Another key skill of complex thinking is the ability for students to make complex ideas understandable, using data visualization, media, and other communications techniques. This year, the California Department of Education launched a taskforce to restore arts in the education as a means of bolstering critical thinking,[201] tying skills such as media production and interactive design to career readiness.[202] However, success in scaling the teaching of complex thinking will require the leaders to bridge disciplines to create new curriculum that prepares students for the future workforce. Harvard University reports the explosion of big data has prompted a need for data scientists across all industries that specialize in the interpretation and communication of massive amounts of data — a skill not yet taught in schools.[203] Notable publications in India report that data scientists are valued highly and very well compensated across the country.[204] If data science is expected to become a major standard for decision-making, schools will be expected to shape learners who have complex thinking skills and can use data and visualizations to support their reasoning.

Implications for Policy, Leadership, or Practice

Policymakers are developing initiatives that place complex and computational thinking at the forefront of education agendas. England's National Curriculum encompasses four key stages to developing this

thinking in students.[205] This curriculum elevates computer science as a foundational discipline for every child to master — just like reading and mathematics.[206] For countries without a clear path to complex thinking mandates, solving this wicked challenge will require the development of effective standards that serve as precursors to official policies. The National Council for Excellence in Critical Thinking (NCECT) was founded with the mission of articulating and fostering intellectual standards in critical thinking research, scholarship, and instruction.[207] One of their main goals is to be able to assess programs that claim to cultivate high-order critical thinking, which would provide school leaders with standardized methods when building their approaches.

Leaders in this area are creating websites and online portals that contain high-quality resources for teaching and evaluating complex thinking. Virtual best practices networks are paving the way for solutions. Through their website, the Area 267 Education Agency in Iowa provides educators and families with key definitions and frameworks for teaching complex thinking as well as incorporating it into formal assessments.[208] Their model contains assessment checklists along with student and teacher rubrics that include a number of concrete skills related to complex thinking. For example, they correlate skills such as comparing, classifying, and deduction as part of the "Extending and Refining Knowledge" rubric, and problem-solving and experimental inquiry as components of the "Using Knowledge Meaningfully" rubric.

Educators can look to Scandinavian countries where coding programs are already well underway to bolster complex thinking across young student populations. In Norway, the initiative Kidsakoder is helping teachers learn how to implement coding programs such as Scratch and LegoNXT in their classrooms.[209] Additionally, several Swedish extracurricular programs are also using Coder Dojo to teach young learners how to develop mobile apps and games.[210] At a district level, Fairfax County Public Schools in Virginia have recognized the importance of critical thinking in kindergarten through sixth grade and designed lessons that evoke nine different strategies, including mind-mapping and decision-making.[211]

For Further Reading

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

Code.org
go.nmc.org/codeorg
(Code.org, accessed 6 April 2015.) Code.org is a nonprofit seeking to expand participation in computer science by making it available in more schools. They have been able to help effect policy change to support computer science curriculum in 16 states. > *Policy*

Computational Thinking in Primary Schools
go.nmc.org/compthink
(Miles Berry, *An Open Mind*, 2014.) Recent changes in the primary school National Curriculum in England focus on "computational thinking," which this author defines as looking at problems or systems in a way that considers how computers could be used to help solve or model them. > *Policy*

Creative Computing
go.nmc.org/creacompu
(Christan Balch et al., *ScratchEd*, 2014.) Researchers at the Harvard Graduate School of Education created a Creative Computing curriculum guide released under a Creative Commons license. This guide explains how Scratch can be used to support familiarity and increasing fluency with computational creativity and computational thinking to expand the options students have for expressing their learning creatively. > *Leadership*

eCity Environment Specification
go.nmc.org/ecit
(eCity Project, September 2014.) The eCity project supported by the European Commission is a virtual environment that leverages a problem-based learning pedagogy in which students develop their critical, lateral, and creative thinking; problem-solving skills; and group collaboration and communication skills. > *Leadership*

Makers Playground - Stimulating the Next Generation of Entrepreneurs in Brussels
go.nmc.org/nextentre
(GE Reports Europe, 16 February 2015.) The organization JA-YE is working to integrate business skills into primary, secondary, and university curriculum through GE Garage in Brussels — a creative space that opens up GE's equipment to students, acquainting them with modern tools and manufacturing practices. > *Practice*

There's a Better Way to Teach Critical Thinking: 9 Rules of Thumb
go.nmc.org/bettway
(Saga Briggs, Open Colleges, 13 September 2014.) This article examines the origin of the term "critical thinking" and helps to clarify what this means in today's classroom. The author provides tips for incorporating critical thinking into the way students write essays, as well as in how discussions and assessments are carried out. > *Practice*

Important Developments in Educational Technology for K-12 Education

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

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

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

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

In the first round of voting, the expert group reduced the master set to 12 technologies that were then researched in much greater depth by the NMC staff. Each was then written up in the format of the *NMC Horizon Report* and used to inform the final round of voting. Technologies that do not make the interim results or the final report are often thoroughly discussed on the project wiki at k12.wiki.nmc.org. Sometimes a candidate technology does not get voted in because the expert panel believes it is already in widespread use in K-12 education, or, in other cases, they believe the technology is more than five years away from widespread adoption. Some technologies, while intriguing, do not have enough credible project examples to substantiate them.

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

> **Consumer technologies** are tools created for recreational and professional purposes and were not designed, at least initially, for educational use — though they may serve well as learning aids and be quite adaptable for use in schools. These technologies find their ways into institutions because people are using them at home or in other settings.

> **Digital strategies** are not so much technologies as they are ways of using devices and software to enrich teaching and learning, whether inside or outside of the classroom. Effective digital strategies can be used in both formal and informal learning; what makes them interesting is that they transcend conventional ideas to create something that feels new, meaningful, and 21st century.

> **Enabling technologies** are those technologies that have the potential to transform what we expect of our devices and tools. The link to learning in this category is less easy to make, but this group of technologies is where substantive technological innovation begins to be visible. Enabling technologies expand the reach of our tools, make them more capable and useful, and often easier to use as well.

> **Internet technologies** include techniques and essential infrastructure that help to make the technologies underlying how we interact with the network more transparent, less obtrusive, and easier to use.

> **Learning technologies** include both tools and resources developed expressly for the education sector, as well as pathways of development that may include tools adapted from other purposes that are matched with strategies to make them useful for learning. These include technologies that are changing the landscape of learning, whether formal or informal, by making it more accessible and personalized.

> **Social media technologies** could have been subsumed under the consumer technology category, but they have become so ever-present and so widely used in every part of society that they have been elevated to their own category. As well established as social media is, it continues to evolve at a rapid pace, with new ideas, tools, and developments coming online constantly.

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

The following pages provide a discussion of the six technologies highlighted by the 2015 K-12 Expert Panel, who agree that they have the potential to foster real changes in education, particularly in the development of progressive pedagogies and learning strategies; the organization of teachers' work; and the arrangement and delivery of content. As such, each section includes an overview of the technology; a discussion of its relevance to teaching, learning, or creative inquiry; and curated project examples and recommendations for further reading.

Consumer Technologies
- 3D Video
- Drones
- Electronic Publishing
- Quantified Self
- Robotics
- Tablet Computing
- Telepresence
- Wearable Technology

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

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

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

Social Media Technologies
- Crowdsourcing
- Online Identity
- Social Networks

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

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

Bring Your Own Device (BYOD)

Time-to-Adoption Horizon: One Year or Less

BYOD, also referred to as BYOT (Bring Your Own Technology), refers to the practice of people bringing their own laptops, tablets, smartphones, or other mobile devices with them to the learning or work environment. Intel coined the term in 2009, when the company observed that an increasing number of its employees were using their own devices and connecting them to the corporate network. In schools, the BYOD movement addresses the same reality; many students are entering the classroom with their own devices, which they use to connect to the school's network. While BYOD policies have been shown to reduce overall technology spending, they are gaining traction more so because they reflect the contemporary lifestyle and way of working. Although administrators and educators have cited IT security concerns, technology gap issues, and platform neutrality as challenges to the uptake of this technology, a growing number of models in practice are paving the way for BYOD to enter the mainstream. Adoption is growing rapidly as was evidenced in a 2014 Consortium for School Networking (CoSN) survey that found that 81% of respondents either had a BYOD policy in place or were planning to deploy one.[212]

Overview

The link between the use of personal devices and increases in productivity gets stronger each passing year as more organizations adopt BYOD policies. The integration of personal smartphones, tablets, and PCs into the workflow supports an on-the-go mentality, changing the nature of work and learning activities so that they can happen anywhere, at anytime. Employers and schools are finding that when given the opportunity to choose their device, users are saved from the effort and time needed to get accustomed to new devices and can therefore accomplish tasks with ease and efficiency.[213] A recent study by Gartner predicted that by 2018, twice as many employee-owned devices will be used for work purposes than enterprise-owned devices.[214]

The success of BYOD aligns with global trends toward mobility as more people, from children to adults, own mobile devices and are accessing the Internet in increasingly different environments for learning. Gartner projected that the worldwide total of PC, tablet, ultramobile, and mobile phone sales would reach 2.4 billion units in 2014[215] and that by 2018 over fifty percent of users will access the Internet via tablet or smartphone.[216] Internationally, the United States was the largest mobile learning buying country in 2014, but by 2019 China is projected to overtake the United States due to a number of factors including adoption of tablets and digital content in Pre-K through 12 schools.[217]

A number of reports are showing that BYOD is gaining acceptance in schools all over the world. Research from the nonprofit Mobile Future in the US highlighted that 43% of Pre-K through 12th-grade students use a smartphone and 73% of middle and high school teachers use cellphones for classroom activities.[218] In Canada, "Digital Learning in Ontario Schools" noted that 58% of schools reported that students were using their own devices.[219] The report "ICT Trends in Australia" revealed that in 2014 there was a 77% rise in the adoption of 1:1 compared to 2013, and that an increasing number of schools are structuring their programs around student/parent-owned devices.[220] In Europe, a 2014 survey of over 500 teachers, department heads, and school heads across the United Kingdom found that two-thirds of respondents claimed that BYOD has had an impact on their organization.[221]

Relevance for Teaching, Learning, or Creative Inquiry

For schools, BYOD is less about the devices and more about the personalized content that users have loaded onto them. Rarely do two devices share the same content or settings, and BYOD enables students and educators to leverage the tools that make them most efficient and productive. A growing host of mobile apps include such educational categories as screencasting, content-sharing, electronic note-taking, expression, presentations, and more.[222] Periscope is one of the newest mobile apps being experimented with in schools;[223] this Twitter-integrated app provides mobile livestreaming with archiving capabilities.[224] With the ability for broadcasters to annotate their video and for viewers to directly engage with the livestream on an individual level, the tool is poised to impact teaching and learning. Since its introduction, teachers have been thinking about how to use it in BYOD environments for demonstrations, virtual field trips, live performances, help with homework, and more. [225]

BYOD has profound implications for K-12 education because it creates the conditions for student-centered learning to take place. For years, schools have worked hard to keep students' cell phones out of the classroom. In March of 2015, the New York City Department of Education finally lifted the ban on cell phone use.[226] As the result of many similar changes, BYOD is aiding student-centered learning in schools worldwide. At Gaston County Schools in Texas, Spanish students choose topics that they are passionate about and use their smartphones as research tools. In this sense, BYOD policies are inherently changing teachers' roles from lecturers to facilitators.[227] The Poway Unified School System created an entirely new school based on a student-centered, BYOD-enabled approach. Called Design39Campus, the school emphasizes project-based learning and personalization. When the teacher, referred to as a "learning experience designer," incorporates a blog into a lesson to teach writing skills, students can immediately turn to their mobile devices to begin working.[228]

The use of personal computing devices in the classroom is seen as a way to either supplement 1:1 situations or to test online learning environments before expending large financial investments, or when resources are limited.[229] According to ISTE, BYOD and 1:1 provides students access to digital learning tools across the curriculum and calls for teachers to rethink learning activities in order to capitalize on school investments.[230] In Australia, the government's Digital Education Revolution provided laptop computers for high school students. Even after the formal program ended, BYOD was still used as a cost-effective mobile learning strategy.[231] Camberwell South Primary School in Victoria, Australia, began introducing tablets into their classrooms in 2011 and over the years, classroom practice began to change as teachers had the opportunity to use and understand the devices. When demand grew for individual use of devices, the school incorporated a BYOD environment that was turned into a 1:1 initiative in the past year.[232]

Bring Your Own Device in Practice

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

Baraboo School District
go.nmc.org/byopol
Baraboo School District's BYOD Policy provides educators the choice over whether they allow student devices in the classroom, and it is very clear about the district not being responsible for loss, theft, or damage to any personal equipment. > *Policy*

Clark County School District Mobile Device Initiatives
go.nmc.org/ccsd
The Clark County School District Policy 5136 allows the use of personal technology and communication devices during instructional time, with the approval of the building principal. In collaboration with the Las Vegas Chamber of Commerce, Las Vegas-Clark County Library District, and local businesses, the district has also established a directory of Wi-Fi partners where students can access free Wi-Fi around the city. > *Policy*

Rogaland Secondary Schools
go.nmc.org/roga
As a mandate from the County Council in Norway, all Rogaland secondary schools have developed BYOD programs with an emphasis on personal laptop computers. > *Leadership*

For Further Reading

The following articles and resources are recommended for those who wish to learn more about Bring Your Own Device:

4 Things You'll Miss by Banning Cellphones In Your Classroom
go.nmc.org/miss
(Robert Sterner, Center for Teaching Quality, 24 February 2015.) Debate over whether students' personal phones should be allowed or banned still remains a hurdle for BYOD policies in many schools. This article explains why allowing students to bring smartphones provides the opportunity for them to learn at an early age how and when it is appropriate to use their devices, how to resist distraction, and other important self-directed learning. > *Policy*

Bennington Joins other Districts Allowing Students to BYOD
go.nmc.org/benn
(Julie Anderson, Omaha.com, 9 February 2015.) Rolling out a BYOD program takes considerable forethought and planning as districts need robust wireless networks and filters, and to train teachers and prepare students and parents, but Bennington Junior-Senior High School, along with many other schools and districts, have found that making the transition pays off. > *Leadership*

The Brutal Authenticity of BYOD
go.nmc.org/authe
(Terry Heick, TeachThought, 6 February 2015.) A BYOD policy can empower learners by providing them pathways to solve problems, access resources, and create their own workflow patterns. It creates a classroom culture that gives students the opportunity to connect their learning in the classroom with their personal lives. > *Practice*

Makerspaces

Time-to-Adoption Horizon: One Year or Less

The turn of the 21st century has signaled a shift in the types of skillsets that have real, applicable value in a rapidly advancing world. In this landscape, creativity, design, and engineering are making their way to the forefront of educational considerations, as tools such as robotics, 3D printers, and web-based 3D modeling applications become accessible to more people. Makerspaces are increasingly being looked to as a method for engaging learners in creative, higher-order problem-solving through hands-on design, construction, and iteration.[233] The driving force behind makerspaces is rooted in the Maker movement, a following comprised of artists, tech enthusiasts, engineers, builders, tinkerers, and anyone else with a passion for making things.[234] The foundation of the Maker movement was built on the success of the Maker Faire, a gathering that launched in 2006 and has since propagated itself into numerous community-driven events all over the world.[235] School leaders are considering the addition of makerspaces into the formal learning environment to encourage students and teachers to act on their ideas and explore design thinking from start to finish.

Overview

Makerspaces, also referred to as hackerspaces, hack labs, or fab labs, are community-oriented workshops where tech enthusiasts meet regularly to share and explore electronic hardware, manufacturing and mechanical tools, and programming techniques and tricks.[236] Much of the hype around this cultural trend burgeoned around the advent of MakerBot printers, a rapid-prototyping technology that requires a DIY mentality to assemble, operate, and replicate.[237] Tools that are commonly found in makerspaces include laser cutters, soldering irons, Arduinos and Raspberry Pi computers, saws and drills, and circuitry gadgets, as well as analog tools such as Legos and sewing devices. The value of these spaces is also in community members who provide a resource of expertise. Makerspaces are places where anyone, regardless of age or experience, can exercise their ingenuity to construct tangible products. For this reason, many schools are seeing their potential to engage learners in hands-on learning activities.

Widespread enthusiasm behind makerspaces has helped the concept gain global traction. The CEO of Maker Media and creator of Maker Faire is a major advocate of installing makerspaces into learning environments, and has helped make it a part of national discussions about innovative approaches to education. Recently, the White House hosted its first ever Maker Faire, leading President Obama to publicly highlight the power of DIY to revolutionize American manufacturing and stoke innovation and job growth.[238] Makerspaces are also catching on in other parts of the world; in China, an increasing number of community makerspaces, called Chaihuo, are populating major cities and mass-production hubs such as Shanghai and Shenzhen. Industry experts believe these making centers will help China stay competitive by cultivating creativity and experimentation among Chinese entrepreneurs whose innovative products will give the country an edge in the global economy.[239]

While many makerspaces are founded to promote creative expression through design and construction, they also have the more pragmatic purpose of being start-up accelerators and tech incubators for local communities. Since its start in 2013, the Garagem, a Brazilian community fab lab in São Paulo, has evolved from a workshop equipped with an open source 3D printer to a platform that nurtures up-and-coming entrepreneurs by helping them find funding and gain visibility. The founder envisions that these successfully incubated companies will co-finance the space so that it can be free and open for everyone.[240] Business experts highlight the positive ripple effect of successful product-launch on the growth of local economies; new companies have a range of legal, marketing, and packaging needs, which can be fulfilled by regional providers.[241] Makerspace communities have also leveraged other avenues including Kickstarter and Etsy.

Relevance for Teaching, Learning, or Creative Inquiry

Public and school libraries are spearheading the makerspace movement in K-12 education. In Fryslân, Netherlands, a mobile fab lab called Frysklab was started by the city's public library to bring maker curriculum and tools to young learners in rural areas. Targeted toward primary and secondary students, the Frysklab course focuses on using digital fabrication to solve local challenges including water technology, sustainable

energy, and new craftsmanship, among other 21st century themes. The Frysklab has been actively recruiting educational partners and schools for support, and is currently developing a program called Fab the Library!, which will guide libraries through the stages of incorporating a fab lab.[242] The library at the International School at Dundee in Greenwich, Connecticut has been transformed into a "learning commons," which features a makerspace in addition to new classes that are co-taught by teachers and the library's media specialists.[243]

Schools are turning to makerspaces to facilitate activities that inspire confidence in young learners, and help them acquire entrepreneurial skills that are immediately applicable in the real world. Eighth-grade students at Garden Street Academy in Santa Barbara, California organized a holiday boutique where they sold products they created in their makerspace, as part of their entrepreneur unit in language arts. The students donated the money they collectively earned to area nonprofits.[244] The Possible Project (TPP) in Massachusetts is one of the latest ventures that combines business education and making for students.[245] The nonprofit provides a three-year afterschool program that teaches high school students from low-income neighborhoods how to create and run a business. Housed in an 1,800 square-foot workshop, TPP has collaborated with the Cambridge Housing Authority and Biogen Idec Foundation to increase access to a specialized type of education that will help disadvantaged youth become business leaders.[246]

Makerspace education also has the potential to empower young people to become agents of change in their communities. The International Development Innovation Network, from MIT's D-School, recently awarded five grants to makerspace projects around the world, including an all-girls high school in Sierra Leone that intends to create opportunities for young women to gain familiarity with the design thinking process.[247] A 2014 FabLearn Fellow from Stanford University has created the Happy Feet project to set up mobile centers that will teach poor communities how to design and make their own 3D printed shoes to protect themselves from fleas, a struggle that has led approximately 50,000 students to drop out of Nairobi schools due to infections.[248] The Happy Feet project leader posits that access to maker education and tools will help alleviate the greater issue at hand, like poverty, by enabling youth to learn skills that can be applied to solving local problems.[249]

Makerspaces in Practice

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

Maker Ed
go.nmc.org/maked
Maker Ed is a nonprofit organization that focuses on both online and in-person professional development, network, community, and capacity building, as well as resource and model sharing to allow educators to integrate making into their current settings and prepare them to train others. > *Leadership*

Sierra Vista Students Create in MakerSpace Lab
go.nmc.org/sierr
Sierra Vista has seen significant increases in attendance, math scores, and rising interest in science and engineering careers since the addition of their makerspace. > *Leadership*

Transforming Monticello High's Library Into the Creative Hub of the School
go.nmc.org/monti
Monticello High School gradually transformed their library into a more flexible learning environment that encompasses a technology exploration space, a music creation lab, and smaller collaborative learning areas with a variety of tools for educators and students to create the objects they envision. > *Leadership*

For Further Reading

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

Facebook Pitches in on 'Makerspaces,' Giving Disadvantaged Students Chances to Tinker
go.nmc.org/pitc
(Angela Swartz, *Silicon Valley Business Journal*, 19 May 2015.) Ravenswood Makerspace Collaborative is being supported by nearby businesses, organizations, and universities, including Facebook, the Ravenswood Education Foundation, and Stanford's Transformative Technologies Lab. > *Leadership*

Making Matters! How the Maker Movement Is Transforming Education
go.nmc.org/matters
(Sylvia Libow Martinez and Gary S. Stager, *We Are Teachers*, 3 April 2015.) This article underscores that making is about understanding the world, not about the physical tools in the lab. > *Leadership*

Inquiry-Based Arts and Engineering Space Enriches Student Learning
go.nmc.org/enriches
(Peter Balonon-Rosen, *Learning Lab*, 11 March 2015.) Malden High School has transformed a near-abandoned woodworking shop into a hub for inquiry-based arts and engineering projects at the high school that appeals to not just engineering students, but anyone who wants to create. > *Practice*

3D Printing

Time-to-Adoption Horizon: Two to Three Years

Known in industrial circles as rapid prototyping, 3D printing refers to technologies that construct physical objects from three-dimensional (3D) digital content such as 3D modeling software, computer-aided design (CAD) tools, computer-aided tomography (CAT), and X-ray crystallography. A 3D printer builds a tangible model or prototype from the electronic file, one layer at a time, through an extrusion-like process using plastics and other flexible materials, or an inkjet-like process to spray a bonding agent onto a very thin layer of fixable powder. The deposits created by the machine can be applied very accurately to build an object from the bottom up, layer by layer, with resolutions that, even in the least expensive machines, are more than sufficient to express a large amount of detail.[250] The process even accommodates moving parts within the object. Using different materials and bonding agents, color can be applied, and parts can be rendered in plastic, resin, metal, tissue, and even food. This technology is commonly used in manufacturing to build prototypes of almost any object that can be conveyed in three dimensions.

Overview

The earliest known examples of 3D printing were seen nearly 25 years ago at the University of Texas at Austin, where selective laser sintering was developed, though the equipment was cumbersome and expensive.[251] The term 3D printing itself was coined a decade later at MIT, when graduate students were experimenting with unconventional substances in inkjet printers.[252] Since 3D printing appeared in the first *NMC Horizon Report* in 2004, the technology has helped the US Department of Defense to inexpensively create aerospace parts, architects create models of buildings, medical professionals develop body parts for transplants, and much more. The 3D printing market is growing rapidly around the globe; Canalys forecasts that 3D printer sales, materials, and associated services should rise from $2.5 billion dollars in 2013 to $16.2 billion dollars by 2018.[253] Currently, the United States, Japan, Germany, China, the United Kingdom, Italy, France, and the Republic of Korea hold the largest share of the 3D printing industry market, but Latin American countries are beginning to advance in this area.[254]

During the process of 3D printing, the users start by designing models of the desired objects through specialized software, such as CAD. While a variety of companies produce CAD software, AutoDesk is the acknowledged leader in the development of such tools.[255] 3D scanning technology, an alternative to model designing, is evolving quickly and yielding new approaches. Microsoft, for example, developed the Kinect as a gaming system, but their technology also enables the digitizing of real objects through 3D scanning.[256] Experiments in the mobile realm provide a glimpse into the future of this visualization technology. Researchers from ETH Zurich's Computer Vision and Geometry Group have created an app that transforms a smartphone to be a portable digital scanner[257] and researchers at CalTech have designed a new camera sensor containing a tiny chip called a nanophotonic coherent imager to capture height, width, and depth information from each pixel.[258]

The adoption of 3D printing is also being fueled by online applications such as Thingiverse[259] and MeshLab,[260] repositories of free, digital designs for physical objects where users can download the digital design information and create that object themselves. The MakerBot is one of the most notable brands of 3D desktop printers that allow users to build everything from toys to robots, to household furniture and accessories, to models of dinosaur skeletons. Relatively affordable at under $2,500, the MakerBot was the first 3D printer designed for consumer use.[261] RepRap is a community open source project that has also stimulated the rise in making; for about $1,000 individuals can buy a RepRap kit and build their own device.[262] Because of the inherent ability for users to create something, whether original or replicated, 3D printing is an especially appealing technology as applied to active and project-based learning in K-12 education.

Relevance for Teaching, Learning, or Creative Inquiry

One of the most significant aspects of 3D printing for education is that it enables more authentic exploration of objects and concepts that may not be readily available to schools. For math, it can help students visualize graphs and mathematical models; in geography, 3D printing can help students better understand geological

formations at scale; and in history, replicas of ancient artifacts can enable more hands-on learning.[263] Literature classes can also benefit from the ability to enable a deeper exploration of concepts. At Mt. Blue High School in Maine, students used a 3D printer to create an art installation that helped demonstrate their comprehension of concepts from the graphic novel, *Watchmen*.[264] Indeed, 3D printing is a promising new way for artistic expression and scientific concepts to come together to encourage STEAM learning.

Some of the most compelling progress of 3D printing in schools comes from the communities that are forming around the tool's potential to enhance more authentic learning. Scots College in Sydney, Australia, was the first school in New South Wales to teach 3D printing and design to students through Makers Empire's Lighthouse School Program. They are part of a selective group that receives early access to app, module, and lesson plan updates in exchange for feedback on the usage and implementation of the software and activities. One notable lesson involved an examination of UNESCO World Heritage sites and their importance to society. Students hand-drew 2D examples of sites such as the Egyptian Sphinx and the Eiffel Tower and then proceeded to enliven their study through the creation of 3D World Heritage site designs using modeling software.[265]

For 3D printing to gain additional traction in schools adequate training is needed to ensure teachers and students have the digital competency needed to turn their ideas into reality. In Massachusetts, Sizer School leaders recognized that piloting a 3D printing program required exposing as many students and teachers as possible to the new tools, but they did it in a very structured manner. By partnering with NVBOTS, a company that provides end-to-end 3D printing solutions for schools, Sizer School was able to administer in-depth training to two teachers and six students so that at least one student printer-technician and one teacher administrator was present in each class. This type of training and management was critical to enabling teachers and students to learn 3D design and printing and incorporate it more seamlessly into lesson plans.[266] Substantial growth of 3D printing in schools around the world is anticipated; for example, the Chinese government has created new policy that will install a 3D printer in nearly 400,00 schools over the next two years.[267]

3D Printing in Practice

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

Guangzhou City, China Offers 3D Printing Classes to Over 300,000 Students
go.nmc.org/gua
With the help of a network of partners, Guangzhou University hosted ten hours of 3D printing classes for educators and has announced a plan to offer 3D printing courses to over 300,000 students within the 230 K-12 schools located in Guangzhou City. > *Leadership*

Helping Hands in 3D
go.nmc.org/helping
Eighth-grade students at Hughes Academy partnered with volunteer organization E-nabling the Future to create mechanical hands that can be downloaded and printed for less than $50 in materials. Insurance companies will not pay $10,000 for a prosthetic hand fabricated by a medical company as young people will grow out of it within a year, so mechanical hands are helping kids worldwide who were born without hands. > *Leadership*

MakerBots at the Taipei American School
go.nmc.org/taip
The Taipei American School has two 3D MakerBot printers that they are using in the Art + Innovation curriculum and robotics program to teach students the engineering design process. > *Practice*

For Further Reading

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

3D Printers Add A New Dimension To Classrooms
go.nmc.org/dim
(Tommy Peterson, *EdTech Magazine*, 13 January 2015.) This article provides perspectives from a variety of educators who incorporate 3D printing in their classes to explain how the 3D printer adds an experiential element to the classroom. > *Leadership*

3D Printing Becomes Accessible for High School Teachers
go.nmc.org/becomes
(Alexandra Pannoni, *US News*, 21 July 2014.) With the introduction of more affordable 3D printers and 3D pens on the market, many educators are finding that 3D printing offers an exciting and hands-on way for students to access and explore mathematical, engineering, and architectural, as well as English and humanities, concepts. > *Leadership*

How 3D Printing is Changing the Shape of Lessons
go.nmc.org/how3d
(Merlin John, BBC News, 16 April 2014.) Schools throughout the UK are integrating 3D printing into curriculum with promising reactions from young students. > *Practice*

Adaptive Learning Technologies

Time-to-Adoption Horizon: Two to Three Years

Adaptive learning technologies refer to software and online platforms that adjust to individual students' needs as they learn. According to a paper commissioned by the Bill and Melinda Gates Foundation and authored by Tyton Partners, adaptive learning is a "sophisticated, data-driven, and in some cases, nonlinear approach to instruction and remediation, adjusting to a learner's interactions and demonstrated performance level, and subsequently anticipating what types of content and resources learners need at a specific point in time to make progress."[268] In this sense, contemporary educational tools are now capable of learning the way people learn; enabled by machine learning technologies, they can adapt to each student's progress and adjust content in real time or provide customized exercises when they need it. Many school leaders envision these adaptive platforms as new, patient tutors that can provide personalized instruction on a large scale. There are two levels to adaptive learning technologies — the first platform reacts to individual user data and adapts instructional material accordingly, while the second leverages aggregated data across a large sample of users for insights into the design and adaptation of curricula.

Overview

The emergence of adaptive learning technologies reflects a movement in schools towards customizing learning experiences for each individual. The topic first appeared in the *NMC Horizon Report > 2015 Higher Education Edition*,[269] where it is currently making the most progress. Schools across the globe are increasingly recognizing that the one-size-fits-all approach to teaching alienates students who are struggling with specific concepts — along with students who are grasping the material more quickly than their peers.[270] Teachers rarely have the capacity to design curricula and assignments that uniquely cater to every student. Integrating personalized learning was cited as a difficult challenge in this report, and adaptive learning technologies provide a potential pathway for tailoring educational opportunities.

Adaptive learning is best suited to take place in hybrid and online learning environments, where student activities are conducted virtually and can be monitored by software and tracking applications. Historically categorized as intelligent tutoring, adaptive learning takes advantage of the latest developments in artificial intelligence to adjust to students' personal preferences.[271] At the most basic level, the adaptive component of the platforms involve algorithms that employ an "if this, then that" approach. More robust models entail algorithms that link specific concepts and skills from the course to how students are interacting with the material; a student, for example, may spend a disproportionate amount of time reading a single passage that summarizes the Triassic Period, signaling the algorithm to serve up more resources for them to better comprehend the history.

Upon collecting students' behavioral data, adaptive learning technologies often display data visualizations in the form of comprehensive dashboards that can be monitored by teachers.[272] These dashboards present data on a granular level, identifying which students may be at risk of failing their classes with the goal of providing efficient interventions and increasing student retention. On a broader level, adaptive learning dashboards can help teachers and school leaders better evaluate the effectiveness of their curriculum design by examining student data collectively and making comparisons across all classes. However, some pundits worry about cultivating dangerous cultures where schools ultimately replace teachers with computers.[273] A recent article published by the Christensen Institute counters, "More powerful personalization comes from using computers to enable teachers to provide more personalized learning." The compelling nature of adaptive learning resides in the ability for teachers to review automated data about their students to get to know them on a deeper level.[274]

Relevance for Teaching, Learning, or Creative Inquiry

While adaptive learning technologies have the potential to be a game-changer and foster more personalized learning for students while providing institutions with key insights about the effectiveness of their instruction, current applications have been mostly limited to research, development, and pilot programs,[275] justifying the topic's position on the far-term horizon. There is a growing host of companies entirely dedicated to developing adaptive learning platforms for schools,

including Dreambox,[276] ALEKS,[277] RealizeIt,[278] and Sanoma and Knewton.[279] At the beginning of 2015, McGraw Hill and Cerego announced a partnership to develop adaptive language learning tools, with the first language expected to be Spanish.[280] There are inherent implications for foreign language classes and exchanges at school. According to a DeVry Education Group white paper, governments are also responsible for fostering increasing interest. Programs in the US, including Common Core Standards and Race to the Top, are spurring more adaptive learning pilots and activities as a way to keep up with the government mandates and remain competitive.[281]

In the Shanxi Province of China, interactive digital platform provider UMeWorld and China Mobile recently shared plans to expand a K-12 adaptive learning system, UMFun.[282] This announcement came on the heels of launching UMFun in the Guangdong Province in Summer 2014. Since then, more than 240,000 students and teachers have joined UMFun, and the companies are expecting to make the platform available to four additional provinces this year.[283] Adaptive learning technologies are perceived as a way to manage large class sizes by providing personalized experiences. For example, at the David A. Boody Intermediate School in New York, which serves many low-income families, there are around 150 students in a single math class. Based on data monitoring in adaptive software, the teacher was able to better tailor a lesson on multiplication to help 20 students who were previously struggling with it.[284]

A first-grade teacher at Mountain View Elementary in Illinois piloted the new Moby Max adaptive online learning program,[285] which incorporates gamification in the form of "leveling up." Students demonstrated significant growth in testing and expressed excitement when they reached new levels. The platform is customizable for teachers so they can incorporate their own lessons and continuously assess students as they gain new proficiencies.[286] While these anecdotes show promise for K-12 learning, there is another dimension where adaptive learning is increasingly providing support — higher education placement. The data generated in the platforms and software is evidence of competency and skill mastery; when students have the ability to tangibly prove what they have learned over the years in school, they can be placed in college courses that better accommodate their needs.[287]

Adaptive Learning Technologies in Practice

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

Dreambox Learning at IDEA Public Schools
go.nmc.org/idea
IDEA Public Schools, a network of tuition-free public charter schools, is using a blended learning model that incorporates the adaptive Dreambox Learning Math software, which engages students with gamification features and helps students drive their own learning. > *Leadership*

INTUITEL
go.nmc.org/intu
The INTUITEL system, funded by education partners from the EU, monitors each learner's progress and behavior, combines these data with pedagogical and methodological knowledge, and then deduces optimal guidance and feedback. > *Leadership*

Guaxy
go.nmc.org/guax
Guaxy is an adaptive web application currently being used in schools in the São Paulo State of Brazil. Teachers assign students homework to be completed through the web application, which collects data showing student performance and provides remediating material to reteach concepts not fully understood. > *Practice*

For Further Reading

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

White Paper: Adaptive Learning Systems
go.nmc.org/syste
(Steven Oxman and William Wong, DeVry Education Group and Integrated Education Solutions, February 2014.) This paper analyzes the structure of adaptive learning systems and how they have been used in various contexts in K-12 education. > *Leadership*

Adaptive Learning Technology: What It Is, Why It Matters
go.nmc.org/altech
(Brian Fleming, *Eduventures*, 1 April 2014.) Adaptive learning technologies can increase student success through personalized learning and analytics, but present challenges for schools that must navigate relationships with third-party vendors. > *Practice*

The Power of Small Data
go.nmc.org/small
(Greg Thompson, *THE Journal*, 1 May 2015.) This article explains how adaptive software is a vital part of many personalized education plans, and gives a variety of examples of how schools and educators are benefitting from the aid of interactive software and the important formative data it provides. > *Practice*

Digital Badges

Time-to-Adoption Horizon: Four to Five Years

Badges are seen as a way to grant certification for formal and informal learning in the form of microcredits, which assess learned skills based on outcomes, rather than seat time.[288] Often viewed as a component of gamification, digital badges are being implemented to help track, capture, and visualize learning in a way that incentivizes students. The concept behind badging embodies historical models of recognition for personal skills and achievement, such as when a Boy or Girl Scout earns a merit badge. Currently, digital badging systems are gaining traction in many online learning environments including Khan Academy, with promising results. One key development that has helped the progress of digital badges was the Open Badge Initiative (OBI) — an open specification for badging established by the Mozilla Foundation, which enables providers and users alike to display achievements on the web, on any platform.[289] More schools are looking to digital badges as an alternative method of validating formal and informal achievements, not just for students, but for teachers, too. While badges are not yet pervasive in education, they are being used by educators and organizations that are seeking comprehensive approaches to demonstrate a student's learning path — methods that encompass far more than grades and traditional credits.

Overview

There have been a number of fundamental collaborations that have been essential to the badging movement. In 2012, the MacArthur Foundation awarded nearly $2 million to 30 proposals about badging schemes, and funded researchers as they evaluated the progress of these pilot projects.[290] Around the same time, the Mozilla Foundation launched Open Badges, a collaboration with the MacArthur Foundation and HASTAC, to develop digital micro credentials that can be created, issued, verified, and shared freely anywhere on the web.[291] The partnership with Open Badges led to the creation of Badge Alliance, a coordinated movement to explore the open badging ecosystem, which was launched in 2014.[292] Currently, there are 13 working groups associated with the Badge Alliance split between focuses on infrastructure and ecosystem.[293] Although digital badges are still in their infancy in K-12 environments at the global level, this technology is gaining traction as successful pilots are being scaled and replicated largely in the US.

Positioned on the far-term horizon, digital badging systems have generated a lively debate about their efficacy. On one side, educators are wary of the way digital badges influence a learner's motivation to learn; that is, the focus on collecting badges may create an extrinsic source of motivation, especially if the students want to one up each other, a characteristic of gamified environments. On the other hand, teachers believe that the existing framework, which is dependent on grades, results in similar outcomes. For this reason, there are a growing number of educators who see badges as a welcome alternative that offers more concrete depictions of what a student has achieved, and their irrevocability rewards learners in ways that grades do not.[294] The former Director of Badge System Design at Mozilla has advocated for badges, citing the prismatic value of these digital microcredits. In response to the question of their worth, the badging expert points to various spectral components including personal, institutional, social, consumer, and generic values.[295]

The potential of badging to recognize achievements and foster the prolonged engagement of learners has been explored across many different sectors, and by many types of institutions, including municipalities. One of the earliest and largest applications of badging was implemented by the City of Chicago. In 2013, the Chicago Summer of Learning (CSOL) was launched by the Mozilla Open Badges team with three main goals: to help every youth in Chicago learn something and gain evidence of that learning; to encourage discovery and motivate more learning; and to communicate that learning to schools and businesses in the fall.[296] With over 100 participating organizations including libraries, museums, and community centers, CSOL was the first large-scale badging implementation of its kind, and it was deemed a success.[297] Shortly after, DePaul University announced that it would accept a selection of badges earned through CSOL for credit in their institution.[298]

Relevance for Teaching, Learning, or Creative Inquiry

School districts have adopted digital badges to emphasize and support college readiness among learners. The Corona-Norco Unified School District in California

partnered with Forall Systems to develop "Passport to Success," a badging system that tracks achievements through grades K-12, implemented alongside a college readiness program. The system was developed to help track learning in preparation for further education; currently, the district is working with local community colleges to ensure that completion of the Passport to Success's 12 core badges will guarantee admissions.[299] The NYC Department of Education has a similar badging scheme in place for NYC Connected Foundations, a program aimed at students enrolled in small, second-chance high schools. Powered by BadgeOS™, the badges are awarded upon the completion of challenge-based quests in four areas: digital citizenship, financial literacy, college and career explorations, and arts and culture.[300]

Badges are also being used to innovate teacher professional development, as a number of schools and districts have integrated digital badging to recognize continued education. At New Milford High School in New Jersey, a digital badging website called Worlds of Learning is being used not only to validate teachers' skills, but also to familiarize them with the concept of badging before it is implemented with students. The Worlds of Learning program encourages educators to strive for 13 badges that emphasize skills involving digital technology, which can then be presented alongside their end-of-year portfolios to prove their learning.[301] A similar initiative is taking place in the District of Columbia Public Schools. Supported by research and leadership by Digital Promise, the MyPD pilot program is an effort to digitize and personalize professional development through online modules and stackable digital badges. The microcredits line up with the District's Teaching and Learning standards, which, when completed, enable teachers to renew their license.[302]

Digital badges have been a boon for efforts to validate the acquisition of soft skills such as problem-solving, persistence, communication, and other attributes that are valued by employers. Funded by the European Commission's Lifelong Learning program, the GRASS (Grading Soft Skills) project is focused on building a framework for digital badging that will assess soft skills throughout primary and secondary schools in order to provide educators with a comprehensive story of that learner's path. The ultimate goal is to develop a method of evaluation that will complement traditionally recognized credentials.[303] While full-fledged badging schemes centered on soft skills are still emergent, microcredits for these areas of intelligence are being incorporated into existing badging systems. A contributor for *Remake Learning* cited the "Maker Mindset" badge offered by the TechShop, a Pittsburg makerspace, for describing an instance in which they learned from a mistake. Similarly, learners at The Ellis School earn a "Passionate Perseverance" badge for overcoming setbacks in design challenges.[304]

Digital Badges in Practice

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

Open Badges: 10 Million Better Futures
go.nmc.org/10m
The John D. and Catherine T. MacArthur Foundation, Mozilla, and HASTAC have been working to create the digital platforms needed to transform badging into a trusted, secure, and portable certification process. > *Policy*

Digital Badges/Open Badge Taxonomy
go.nmc.org/taxon
Researchers working on Badge Europe are currently developing a taxonomy that categorizes digital and open badges into three groups: content-related (what the badge represents), issue-related (who issues the badge), and process-related (how the badge was achieved). > *Leadership*

CSTEMBE Badge Implementation at After School Matters
go.nmc.org/aftersc
After School Matters in collaboration with Youtopia is piloting Community STEM Badging Ecosystem digital badges in five STEM programs. > *Practice*

For Further Reading

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

Certifying Skills and Knowledge: Four Scenarios on the Future of Credentials
go.nmc.org/cert
(Jason Swanson, KnowledgeWorks, 2015.) This report describes four possible scenarios for how the credentialing system, beginning with K-12 education, can be transformed to reflect the changing landscape of knowledge acquisition. > *Leadership*

The Next Experiment in Education
go.nmc.org/nextex
(Lindsey Tepe, *TIME Magazine*, 11 April 2015.) The Mozilla and MacArthur Foundations are leading the movement to adopt digital badges and micro-credentials as a way to validate skills gained through professional development. > *Leadership*

Wearable Technology

Time-to-Adoption Horizon: Four to Five Years

Wearable technology technology refers to computer-based devices that can be worn by users, taking the form of an accessory such as jewelry, eyewear, 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, and social media interactions, or, in the case of Oculus Rift and similar gear,[305] it can enable virtual reality. There are even new classes of devices that are seamlessly integrated with a user's everyday life and movements. Over the past year, Google Glass has been one of the most heavily discussed wearables,[306] enabling users to see information about their surroundings displayed in front of them. Smart watches from Apple, Samsung, Sony, and Pebble are already allowing users to check emails and perform other productive tasks through a tiny interface. Thanks to the quantified self movement, today's wearables not only track where a person goes, what they do, and how much time they spend doing it, but now what their aspirations are and when those can be accomplished.[307]

Overview

Wearable technology is not a new category; one of the most popular early incarnations of the technology was HP's calculator watch, which was introduced in the 1980s.[308] Since then, the field has advanced significantly, but the overarching theme behind the technology remains the same — convenience. Portable, lightweight, and often taking the place of an accessory that the user already has, wearable tools are meant to go anywhere. Effective wearable devices, including smart watches, become an extension of the person wearing them, allowing them to comfortably engage in everyday activities, such as checking and responding to emails and other tasks that help teachers and students to stay productive on-the-go and gain new insights about their daily routines.

According to the Consumer Electronics Association, wearable device sales are projected to generate $5.1 billion in revenue in 2015 alone — a 133% increase from 2014. The market is poised for even more substantial growth in the coming years;[309] Head Tech predicts that sales will surpass $12.6 billion by 2018.[310] While these numbers indicate that wearable technology has been embraced in the consumer sector, the implications for K-12 education are still largely undocumented as mainstream adoption is at least four years away. Early applications of these devices include parents equipping young children with GPS-enabled wristbands that track their whereabouts for safety purposes,[311] although this use has surfaced privacy concerns about other people being able to wrongfully access their locations.[312]

Recent uses of wearable devices have roots in the quantified self movement as more people are gathering and analyzing personal data about their daily activities. Nike's Fitbit[313] and Jawbone's UP[314] wristbands connect with apps that display information about how many steps the wearer has taken, their heart rate, and other health-related information, along with providing tailored recommendations for exercise and nutrition. Empowered by these insights, many individuals now rely on these technologies to improve their lifestyle and health. In the face of the widespread obesity epidemic, some pundits are optimistic about these devices having the ability to teach children about nutrition during their most formative years in a physical education context.[315] LeapFrog designed the LeapBand specifically for kids, which encourages them to stay active and even rewards healthy behavior with points and virtual pets.[316] Similarly, the Sqord activity tracker was developed for adolescents and also gamifies exercise, following a growing trend of incentivizing exercise.[317]

Relevance for Teaching, Learning, or Creative Inquiry

As wearable technologies become more sophisticated, teachers are finding unique ways to integrate them into classrooms. At Switzerland Point Middle School in Florida, a technology and TV production teacher lent his GoPro to students, who attached it to a remote control car and drove it around the school to film various events that later appeared in the school's morning announcements.[318] Indeed, wearable technology has been pushing the boundaries of what students are able to create — even spurring wearble-themed school events and contests. Earlier this year, students from nine high schools in Japan participated in a competition to design their own devices. Entrants in the contest included fashionable GPS-enabled wristbands that can

wirelessly connect to an array of mobile apps.[319] MIT's Lincoln Laboratory hosted a similar "Make Your Own Wearables" workshop for high school girls to introduce them to mechanical design and electrical engineering in engaging ways.

When Apple unveiled their smart watch in early 2015,[320] education professionals quickly began speculating about the potential applications, especially the aforementioned health benefits.[321] In Australia, the first Apple Watch trial is underway, led by TAFE English Language and Literacy Service.[322] The goal of this initiative is to pilot the watch as a tool for helping prepare ESL students for the workforce, and makes use of the SAMR learning model.[323] Smart watches in general are even being considered for BYOD programs,[324] forcing schools to revise or rethink their supporting IT infrastructures which currently and almost exclusively factor in laptops, tablets, and smartphones.

In terms of addressing specific learning and mobility needs, wearable technology has profound applications for disabled students. Starkey's Halo hearing aids, for example, sync with an iTunes app to enable hearing-impaired users to answer phone calls through their watches, mute unwanted noises, and stream music directly into their ears with no cord.[325] Georgia Institute of Technology is developing a tongue magnet that can control wheelchairs, computers, and smartphones to support people afflicted with severe spinal cord injuries.[326] These kinds of discreet and seamless wearables can help level the playing field for disabled students, allowing them to engage in the same kinds of physical and learning activities as their peers.

Wearable Technology in Practice

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

Boston Elementary Students Take on Fitness for a Good Cause
go.nmc.org/unicef
The US Fund for UNICEF has launched Kid Power, a 30-day initiative that encourages elementary school-age kids in Boston, Dallas, and New York to engage in movement-based curriculum that leverages UNICEF Kid Power fitness bands, displaying how many steps are taken and points earned, to monitor a student's physical activity. > *Leadership*

North School Leads in Wearable Technology Innovation
go.nmc.org/wick
In Scotland, Wick High School's wearables design competition challenged its students to design an app for use with Google Glass eyewear or Samsung Gear 2 and Pebble smart watches. Over the course of two months, the students worked in teams to brainstorm problems that could be solved using one of these platforms. > *Leadership*

SAFE Kids Paxie Band
go.nmc.org/paxie
A GPS-enabled wearable device designed for children called the SAFE Kids Paxie Band measures ambient temperature, GPS location, heart rate, boundary settings, and activity tracking. > *Practice*

For Further Reading

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

Imagining the Classroom of 2016, Empowered by Wearable Technology
go.nmc.org/imagi
(Rick Delgado, *Emerging EdTech*, 20 April 2014.) This article imagines scenarios in which wearable technology would allow a more seamless way for students to capture and reference their learning experiences as well as for students to collaborate and share their work with each other and educators. > *Practice*

The Wear, Why, and How
go.nmc.org/thewear
(*The Economist*, 12 March 2015.) This article describes the challenges current wearables will have to overcome for widespread adoption, contrasted with the appeal of wearables to provide a persistent digital identity melding the functions of a driving license, credit card, house key, car key, and computer in one small device. > *Practice*

Worldwide Wearables Market Forecast to Reach 45.7 Million Units Shipped in 2015 and 126.1 Million Units in 2019, According to IDC
go.nmc.org/idc
(IDC, 30 March 2015.) According to the most recent forecast data from the International Data Corporation (IDC) Worldwide Quarterly Wearable Device Tracker, an increased focus on smart wearables will propel the drive of the worldwide wearables market 45.1% higher in 2015. These devices will include wrist wearables, clothing, eyewear, and earwear. > *Practice*

The 2015 K-12 Edition Expert Panel

Larry Johnson
Co-Principal Investigator
New Media Consortium
United States

Keith Krueger
Co-Principal Investigator
CoSN
United States

Samantha Adams Becker
Horizon Project Director
New Media Consortium
United States

Michele Cummins
Research Manager
New Media Consortium
United States

Troy Bagwell
Decatur Independent School District
United States

Fiona Banjer
Department of Education, Training & Employment, Queensland
Australia

Russell Beauregard
Intel Corporation
United States

Roger Blamire
European Schoolnet
Belgium

Tony Brandenburg
Independent Education Consultant
Indonesia

Deirdre Butler
St. Patrick's College, Dublin
Ireland

Adam Carter
Schutz American School/Cause & Affect Foundation
Egypt

Chun-Yen Chang
National Taiwan Normal University
Taiwan

Leslie Conery
Banyan Tree Partnerships, LLC
United States

Robert Craven
Computer Using Educators (CUE)
United States

Helen Crompton
Old Dominion University
United States

David Deeds
Colegio Americano de Guatemala
Guatemala

Greg DeYoung
Blue Valley School District
United States

Michael Dezuanni
Queensland University of Technology
Australia

Claus Gregersen
Herning Gymnasium
Denmark

Lisa Gustinelli
St. Thomas Aquinas High School
United States

Tony Inglese
Batavia Public Schools
United States

Shafika Isaacs
Independent Consultant
South Africa

Mike Jamerson
Bartholomew Consolidated School Corporation
United States

Øystein Johannessen
Nordland County Council
Norway

Kevin Johnson
Osaka YMCA International School
Japan

Joani Kay
Mountain Brook School District
United States

Alice Keeler
California State University Fresno
United States

Michael Lambert
Concordia International School of Shanghai
China

Maria Langworthy
Michael Fullan Enterprises
United States

Adrian Lim
Infocomm Development Authority of Singapore
Singapore

Julie Lindsay
Flat Connections / Learning Confluence
Australia

Holly Ludgate
Independent Consultant
United States

Marcia Mardis
Florida State University
United States

Cristiana Mattos Assumpçao
Colégio Bandeirantes
Brazil

Bob Moore
RJM Strategies LLC
United States

Jan Morrison
Washoe County School District
United States

Laura Motta
Board of Uruguay Teacher Education & Plan Ciebal
Uruguay

Kathryn Moyle
Australian Council for Educational Research
Australia

Michael Nagler
Mineola UFSD
United States

Judy O'Connell
Charles Sturt University
Australia

Alex Podchaski
Oak Knoll School of the Holy Child
United States

Allison Powell
iNACOL
United States

Jon K. Price
Intel Corporation
United States

Jenny Grant Rankin
Illuminate Education
United States

Tom Ryan
eLearn Institute
United States

Giselle Santos
Cultura Inglesa RJ/DF/GO/ES/RS
Brazil

Kathy Schrock
Independent Consultant
United States

Len Scrogan
Future Talk
United States

Jeremy Shorr
Mentor Public Schools
United States

Daniela Silva
Qatar Foundation - Qatar Academy Sidra
Qatar

Cheryl Steighner
Camelot Elementary School
United States

Nada Stojičević
Elektrotehnička škola "Nikola Tesla"
Serbia

Kari Stubbs
BrainPOP
United States

Michael Taylor
ISS International School
Singapore

Marta Turcsanyi-Szabo
Eotvos Lorand University
Hungary

Tony Wilhelm
Affiniti
United States

Endnotes

1 http://www.nextgenscience.org/next-generation-science-standards
2 http://www.inacol.org/resource/a-k-12-federal-policy-framework-for-competency-education-building-capacity-for-systems-change/
3 http://www.washingtonpost.com/blogs/answer-sheet/wp/2014/07/25/five-u-s-innovations-that-helped-finlands-schools-improve-but-that-american-reformers-now-ignore/
4 http://www.redjumper.net/blog/2015/01/expand-students-horizons-global-collaboration/
5 http://www.rsc.org/blogs/eic/2014/10/stop-motion-animation-facilitate-group-discussion
6 http://bie.org/about/what_pbl
7 https://www.challengebasedlearning.org/pages/about-cbl
8 http://www.educationworld.com/a_issues/issues/issues417.shtml
9 http://www.opencolleges.edu.au/informed/features/agile-based-learning-what-is-it-and-how-can-it-change-education/
10 http://www.theguardian.com/teacher-network/teacher-blog/2014/feb/05/schools-standards-structures-education-policy
11 http://www.edutopia.org/integrated-studies
12 https://www.aap.org/en-us/about-the-aap/aap-press-room/Pages/Let-Them-Sleep-AAP-Recommends-Delaying-Start-Times-of-Middle-and-High-Schools-to-Combat-Teen-Sleep-Deprivation.aspx
13 http://www.takepart.com/article/2014/08/25/sleep-deprived-teenagers
14 http://www.jmhs.com/academics
15 http://www.academia.edu/3731129/Utilizing_Music_Technology_as_a_Model_for_Creative_Development_in_K-12_Education
16 http://www.bostonpublicschools.org/student-voice
17 https://coopcatalyst.wordpress.com/2013/03/05/what-happens-when-kids-craft-their-own-byod-policy/
18 https://www.whitehouse.gov/issues/education/k-12/connected
19 http://www.smithsonianmag.com/innovation/why-are-finlands-schools-successful-49859555/?no-ist
20 http://www.washingtonpost.com/blogs/answer-sheet/wp/2014/07/25/five-u-s-innovations-that-helped-finlands-schools-improve-but-that-american-reformers-now-ignore/
21 http://www.weareteachers.com/blogs/post/2015/04/01/finland-s-a-schools
22 http://www.oecd-ilibrary.org/education/progression-in-student-creativity-in-school_5k4dp59msdwk-en
23 http://www.davincischools.org/projectbasedlearning.shtml
24 http://www.hightechhigh.org/
25 http://deeperlearning4all.org/about-deeper-learning#sthash.fjV7WQEE.dpuf
26 http://www.pbl.uci.edu/whatispbl.html
27 http://www.teachinquiry.com/index/Introduction.html
28 http://hechingerreport.org/deeper-learning-improves-student-outcomes/
29 http://www.theatlantic.com/education/archive/2014/12/the-pursuit-of-deeper-learning/383308/
30 http://www.air.org/resource/evidence-deeper-learning-outcomes-3-3
31 http://www.sri.com/sites/default/files/publications/pbis-efficacy-study-y1-outcomes-report-2014_0.pdf (PDF)
32 http://www.sri.com/blog/how-curriculum-materials-make-difference-next-generation-science-learning
33 http://www.cea-ace.ca/publication/facts-education-inquiry-based-learning-effective
34 http://www.edutopia.org/blog/preparing-classroom-culture-deeper-learning-elizabeth-garcia
35 http://www.air.org/resource/deeper-learning
36 https://schoolsonline.britishcouncil.org/regions/east-asia/asean-deep-leaning-policy-engagement-series
37 http://cdno.gettingsmart.com/wp-content/uploads/2014/06/FINAL-Printable-DeeperLearningTeacherPrep.pdf (PDF)
38 http://dlplanningguide.com/wp-content/uploads/2015/01/DL-PlanningGuide-web3.pdf (PDF)
39 http://l1to1.com/whyitworks/
40 http://l1to1.com/howitworks/
41 http://jacksonville.com/news/metro/2014-10-12/story/project-based-learning-vies-time-classrooms
42 https://foundationacademy.net/
43 http://www.cte.cornell.edu/teaching-ideas/engaging-students/collaborative-learning.html
44 https://eacea.ec.europa.eu/sites/eacea-site/files/documents/flcp-guidelines-en.pdf (PDF)
45 http://www.julielindsay.net/2014/08/who-says-global-collaboration-is-hard.html
46 http://www.hipatiapress.com/hpjournals/index.php/ijep/article/view/1087/pdf (PDF)
47 https://research.pearson.com/content/plc/prkc/uk/open-ideas/en/articles/explore-eppse/_jcr_content/par/articledownloadcompo/file.res/Exploring%20Effective%20Pedagogy%20in%20Primary%20Schools.pdf (PDF)
48 http://www.nea.org/tools/16870.htm
49 http://www.cdwnewsroom.com/cdw-cloud-401-report/
50 https://www.proofhub.com/
51 https://www.mindmeister.com/
52 http://www.skype.com/en/
53 http://elearningindustry.com/6-online-collaboration-tools-and-strategies-boosting-learning
54 http://www.iste.org/lead/awards
55 http://www.julielindsay.net/2014/08/who-says-global-collaboration-is-hard.html
56 http://www.globalreadaloud.com/
57 http://learning.instructure.com/2014/10/wired-for-collaboration/
58 http://openeducationeuropa.eu/sites/default/files/DIGCOMP%20brochure%202014%20.pdf (PDF)
59 http://edpolicy.stanford.edu/blog/entry/1223
60 http://www.washingtonpost.com/blogs/answer-sheet/wp/2015/04/09/guiding-principles-for-a-more-enlightened-u-s-education-policy/
61 https://eacea.ec.europa.eu/sites/eacea-site/files/session2hellend.pdf (PDF)
62 http://itlresearch.com/images/stories/reports/ITL%20Research%202011%20Findings%20and%20Implications%20-%20Final.pdf (PDF)
63 http://edpolicy.stanford.edu/node/1208
64 http://www.asiaeducation.edu.au/professional-learning/toolkits/global-collaboration
65 https://www.teachingchannel.org/professional-development-videos/teams
66 http://www.ascd.org/professional-development/institutes/building-teachers-capacity-for-success.aspx
67 http://www.schools.nsw.edu.au/learning/learning-tools/index.php
68 http://www.zdnet.com/article/google-classroom-mobile-ios-android-education/
69 http://www.slj.com/2014/11/industry-news/ebooks-take-hold-slowly/#_
70 http://www.redjumper.net/blog/2015/01/expand-students-horizons-global-collaboration/
71 https://www.educreations.com/
72 http://mathtrain.tv/page.php?page=1
73 http://www.edtechmagazine.com/k12/article/2014/07/qa-teachertube-gives-educators-their-own-video-platform
74 http://www.kcet.org/socal/departures/columns/open-classroom/minecraft-in-schools-a-tool-for-remixing-learning-1.html
75 http://ww2.kqed.org/mindshift/2014/06/06/making-games-the-ultimate-project-based-learning/
76 http://thejournal.com/Articles/2015/02/18/Beyond-Programming-The-Power-of-Making-Games.aspx?Page=1
77 http://www.dontcopyrightme.com/
78 http://www.slj.com/2015/05/technology/3-d-printing-understanding-copyright-fair-use-and-more/#_
79 http://bhstv.bloomfield.org/2908
80 https://www.commonsensemedia.org/educators/scope-and-sequence
81 http://www.rsc.org/blogs/eic/2014/10/stop-motion-animation-facilitate-group-discussion
82 http://www.christenseninstitute.org/wp-content/uploads/2013/04/The-rise-of-K-12-blended-learning.emerging-models.pdf (PDF)
83 http://5a03f68e230384a218e0-938ec019df699e606c950a5614b999bd.r33.cf2.rackcdn.com/MSDF-Blended-Learning-Report-May-2014.pdf (PDF)
84 http://educationnext.org/teacher-autonomy-blended-learning-usc-hybrid-high-school/
85 http://5a03f68e230384a218e0-938ec019df699e606c950a5614b999bd.r33.cf2.rackcdn.com/MSDF-Blended-Learning-Report-May-2014.pdf (PDF)
86 http://www.christenseninstitute.org/fixing-teacher-education/
87 http://www.inacol.org/our-work/inacol-center-for-policy-advocacy/
88 http://www.inacol.org/resource/a-k-12-federal-policy-framework-for-competency-education-building-capacity-for-systems-change/
89 http://fcl.eun.org/learning-zones
90 http://fcl.eun.org/develop
91 https://www.edsurge.com/n/2014-01-29-blended-learning-sparks-in-south-africa
92 https://www.edsurge.com/n/2014-01-29-blended-learning-sparks-in-south-africa

93 https://www.edsurge.com/n/2014-05-20-pearson-invests-in-blended-learning-in-south-africa-india
94 http://www.sylvanlearning.com/blog/index.php/the-growing-interest-in-stem/
95 http://stemtosteam.org/
96 http://steamedu.com/about-us/
97 http://edtechreview.in/trends-insights/insights/1122-stem-to-steam-learning-learning-science-in-the-21st-century
98 http://www.wsj.com/articles/SB10001424052702304747004579224003721262792
99 http://www.hilburnacademy.net/what-is-steam.html
100 http://www.usnews.com/news/stem-solutions/articles/2014/02/13/gaining-steam-teaching-science-though-art
101 http://www.edutopia.org/blog/pbl-and-steam-natural-fit-andrew-miller
102 http://siouxcityjournal.com/lifestyles/local/art-meets-science-morningside-student-earns-high-marks-for-impressive/article_d3fe7a77-4b4e-5c46-9c2b-69b124a8af4e.html
103 http://education.arts.ufl.edu/resources/stem-vs-steam-girl/
104 https://www.whitehouse.gov/issues/education/k-12/educate-innovate
105 http://www.eun.org/focus-areas/stem
106 http://stemtosteam.org/events/congressional-steam-caucus/
107 http://sd25.senate.ca.gov/education/steam
108 https://www.teachingchannel.org/videos/visual-arts-technology
109 http://roboticsclub.com.au/category/steam-education/
110 http://dixon.schools.detroitk12.org/2015/04/22/steam-in-action/
111 http://youthinactionri.org/steam/
112 http://www.unescobkk.org/education/ict/current-projects/facilitating-ict-pedagogy/
113 http://www.digitalschools.ie/
114 http://www.metis-project.org/index.php/el/news/49-developing-real-world-authentic-learning-through-the-partnership-of-schools-and-enterprises
115 http://tntp.org/assets/documents/TNTP_Blended_Learning_WorkingPaper_2014.pdf (PDF)
116 https://www.edsurge.com/n/2014-04-14-how-a-district-ended-student-dropouts-with-personalized-learning
117 http://www.harloff.no/2013/04/teach-kids-to-code.html
118 http://ww2.kqed.org/mindshift/2014/12/03/what-meaningful-reflection-on-student-work-can-do-for-learning/
119 http://net.educause.edu/ir/library/pdf/eli3009.pdf (PDF)
120 http://patch.com/new-york/peekskill/peekskill-middle-school-students-enhancing-community-sustainability-through-wheelabrator-symposium
121 https://www.americanprogress.org/issues/labor/news/2014/07/14/93768/the-bottom-line-apprenticeships-are-good-for-business/
122 http://www.tascorp.org/policy-documents/learning-beyond-high-school-walls#sthash.hvFqzvut.dpbs
123 http://ec.europa.eu/education/policy/vocational-policy/doc/alliance/work-based-learning-in-europe_en.pdf (PDF)
124 http://www.metis-project.org/index.php/el/news/49-developing-real-world-authentic-learning-through-the-partnership-of-schools-and-enterprises
125 http://www.deseretnews.com/article/865603924/Programs-give-students-real-world-work-experience-in-high-school.html?pg=all
126 http://www.macrothink.org/journal/index.php/jse/article/view/6149
127 http://www.jite.org/documents/Vol14/JITEv14IIPp017-038Theodosiadou0669.pdf (PDF)
128 https://gradedtl.wordpress.com/2015/03/20/students-proud-to-share-eportfolios-on-innovate-2015/
129 http://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1389115469384&uri=CELEX:52013DC0654
130 http://www.advanc-ed.org/source/training-transformation-teachers-technology-and-third-millennium
131 http://www.waldenu.edu/~/media/Files/WAL/full-report-dispelling-five-myths.pdf (PDF)
132 http://www.ipr.northwestern.edu/about/news/2015/wartella-early-education-digital-technology-classroom.html
133 http://askatechteacher.com/2014/07/30/challenges-to-implementing-computer-technology-in-education/
134 http://blog.digedu.com/survey-release/
135 http://essie.eun.org
136 http://www.livemint.com/Opinion/ppdljgMHFmfeFfJBkdxEAL/Empowering-teachers-and-trainers-through-technology.html
137 http://www.icicte.org/Proceedings2013/Papers 2013/05-1-Krumsvik.pdf (PDF)
138 https://www.whitehouse.gov/issues/education/k-12/connected
139 http://www.unesco.org/new/en/media-services/single-view/news/in_kinshasa_unesco_puts_technology_at_the_service_of_teacher_training/#.VS7fZ45VhBc
140 http://www.unescobkk.org/education/ict/current-projects/facilitating-ict-pedagogy/
141 http://www.bizjournals.com/triad/blog/2014/09/unc-greensboro-wins-7-7m-grant-for-technology.html
142 http://www.ijhssnet.com/journals/Vol_3_No_17_September_2013/2.pdf (PDF)
143 http://teach-now.com/overview/
144 http://edukata.fi/
145 http://www.eun.org/academy
146 http://edglossary.org/personalized-learning/
147 http://www.competencyworks.org/wp-content/uploads/2014/10/CW-An-International-Study-in-Competency-Education-Postcards-from-Abroad-October-2014.pdf (PDF)
148 http://www.impatientoptimists.org/Posts/2015/04/At-a-Chicago-Charter-Personalized-Learning-is-Intrinsic#.VW8whqakXQR
149 http://www.alfiekohn.org/blogs/personalized/
150 http://ww2.kqed.org/mindshift/2015/02/02/what-do-we-really-mean-when-we-say-personalized-learning/
151 http://zhaolearning.com/2009/08/06/96/
152 http://www.theprovince.com/life/education/Kids+need+personal+learning+standardized+tests+educators/10771379/story.html
153 http://www.oecd.org/pisa/pisaproducts/46581035.pdf (PDF)
154 http://www.oecd.org/edu/EDUCATION%20POLICY%20OUTLOOK%20FINLAND_EN.pdf (PDF)
155 http://www.competencyworks.org/wp-content/uploads/2014/10/CW-An-International-Study-in-Competency-Education-Postcards-from-Abroad-October-2014.pdf (PDF)
156 http://www.competencyworks.org/wp-content/uploads/2014/10/CW-An-International-Study-in-Competency-Education-Postcards-from-Abroad-October-2014.pdf (PDF)
157 http://learningaccelerator.org/media/ab304e1c/PERSONALIZED%20LEARNING%20IN%20PROGRESS.pdf (PDF)
158 http://www.publiccharters.org/wp-content/uploads/2014/09/NAPCS-NextGen-Report-DIGITAL.pdf (PDF)
159 http://www.futureschoolstrust.com/assets/Cornwallis%20Prospectus_2015-16.pdf (PDF)
160 https://www.edsurge.com/n/2014-04-14-how-a-district-ended-student-dropouts-with-personalized-learning
161 http://www.iste.org/standards/ISTE-standards/standards-for-teachers
162 http://blogs.edweek.org/edweek/DigitalEducation/2014/11/teachers_more_tech-savvy_students.html
163 http://www.bradfordnetworks.com/byod-in-education-new-survey-reveals-widespread-use-and-some-security-surprises/
164 http://www.educationworld.com/a_curr/curr176.shtml
165 http://www.sciencedaily.com/releases/2015/02/150216064735.htm
166 http://www.unesco.org/new/en/tashkent/about-this-office/single-view/news/supporting_competency_based_teacher_training_reformsto_facilitate_ict_pedagogy_integration_in_uzbekistan#.VTpxn2RViko
167 http://www.core-ed.org/thought-leadership/ten-trends/ten-trends-2015/inclusive-design
168 http://ec.europa.eu/languages/policy/strategic-framework/rethinking-education_en.htm
169 http://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52013XG0305(01)&from=EN
170 http://www.ccsso.org/Resources/Publications/InTASC_Model_Core_Teaching_Standards_and_Learning_Progressions_for_Teachers_10.html
171 http://education.ky.gov/teachers/pges/tpges/pages/kentucky-framework-for-teaching.aspx
172 http://tntp.org/about-tntp
173 http://tntp.org/blog/post/what-blended-learning-really-means-for-teachers
174 http://tntp.org/assets/documents/TNTP_Blended_Learning_WorkingPaper_2014.pdf (PDF)
175 http://tn.chalkbeat.org/2014/05/29/blended-learning-pilot-means-a-new-role-for-teachers-in-16-memphis-schools/#.VTpiKmRViko
176 http://tnsatlanta.org/what-is-the-new-school/founding-principles/teachers-are-guides/
177 http://www.cbpp.org/research/most-states-funding-schools-less-than-before-the-recession
178 http://bridgemi.com/2013/09/special-report-michigan-fails-students-with-poor-teacher-prep/
179 http://www.brookings.edu/research/papers/2015/03/05-education-evidence-kane
180 http://raikesfoundation.org/blog/posts/science-tapping-teacher-insights-build-learning-mindsets-and-skills
181 http://www.edweek.org/ew/articles/2014/03/12/24techschool_ep.h33.html
182 http://www.calendow.org/
183 http://www.ssireview.org/articles/entry/we_need_more_scale_not_more_innovation
184 http://gettingsmart.com/2015/04/dln-report-card-preview-creating-innovation-zones-in-west-virginia/
185 http://wvde.state.wv.us/innovationzones/appfaq.html
186 https://gov.georgia.gov/press-releases/2014-12-15/deal-announces-innovation-fund-grant-award-winners
187 http://go.nmc.org/distin
188 http://www.scalingupcenter.org/about-the-center/index.aspx
189 https://www.youtube.com/watch?v=3o6vMDZAjqQ
190 http://lsl.eun.org/home
191 http://fcl.eun.org/documents/10180/19008/LSL_Report+Summary+SEP2014.pdf/264ec04d-5cf1-4d39-9e86-285273fd6c32
192 http://www.teachfirst.org.uk/what-we-do/encouraging-innovation-education-0
193 http://www.iste.org/docs/ct-documents/computational-thinking-operational-definition-flyer.pdf?sfvrsn=2

194 http://www.slideshare.net/jurgenappelo/complexity-thinking?ref=http://less2011.leanssc.org/program/complexity-and-systems-thinking/
195 http://www.economist.com/news/international/21601250-global-push-more-computer-science-classrooms-starting-bear-fruit
196 http://www.wired.com/2013/05/silicon-valley-coders-and-autism-and-asperbergers-maybe-its-a-new-kind-of-design-thinking
197 https://code.org/stats
198 http://www.nytimes.com/roomfordebate/2014/05/12/teaching-code-in-the-classroom/teach-coding-as-early-as-possible
199 http://www.npr.org/sections/alltechconsidered/2014/02/17/271151462/a-push-to-boost-computer-science-learning-even-at-an-early-age
200 http://www.edutopia.org/blog/coding-classroom-long-overdue-inclusion-merle-huerta
201 http://www.cde.ca.gov/nr/ne/yr15/yr15rel10.asp
202 http://www.cde.ca.gov/eo/in/documents/bfcsreport.pdf (PDF)
203 http://www.extension.harvard.edu/hub/blog/extension-blog/why-data-science-jobs-are-high-demand
204 http://timesofindia.indiatimes.com/tech/jobs/Talented-Indian-data-scientists-get-top-dollars/articleshow/27927334.cms
205 https://www.gov.uk/government/publications/national-curriculum-in-england-computing-programmes-of-study/national-curriculum-in-england-computing-programmes-of-study
206 http://www.ibtimes.co.uk/coding-classroom-computational-thinking-will-allow-children-change-world-1463493
207 https://www.criticalthinking.org/pages/the-national-council-for-excellence-in-critical-thinking/406
208 https://www.aea267.k12.ia.us/curriculum/instruction/complex-thinking-skills-reasoning/
209 http://www.harloff.no/2013/04/teach-kids-to-code.html
210 http://sverigesradio.se/sida/artikel.aspx?programid=2054&artikel=5726877
211 http://www.fcps.edu/is/aap/level1.shtml
212 http://www.edtechmagazine.com/k12/article/2015/04/byod-expands-its-reach
213 http://education.alberta.ca/media/8640236/tech-briefing-byod.pdf (PDF)
214 http://www.gartner.com/newsroom/id/2909217
215 http://www.gartner.com/newsroom/id/2791017
216 http://www.gartner.com/newsroom/id/2939217
217 http://www.ambientinsight.com/Reports/MobileLearning.aspx
218 http://mobilefuture.org/resources/edtech-mobile-learning/
219 http://www.peopleforeducation.ca/wp-content/uploads/2014/03/digital-learning-2014-WEB.pdf (PDF)
220 http://www.csa.edu.au/documents/item/347
221 http://www.businesscomputingworld.co.uk/news/pressrelease/uk-schools-increase-byod-adoption-as-pace-of-evolution-increases/
222 http://www.edutopia.org/blog/the-epic-byod-toolchest-vicki-davis
223 http://www.abc57.com/story/29063721/cool-schools-virtual-field-trip-using-periscope-app
224 http://dailygenius.com/new-periscope-app/
225 https://whatsnotwrong.wordpress.com/2015/05/13/a-dozen-cool-ways-to-use-periscope-in-your-class/
226 https://www.graphite.org/blog/the-beginning-of-byod-in-new-york-city-schools
227 http://www.gaston.k12.nc.us/site/default.aspx?PageType=3&DomainID=4&ModuleInstanceID=66&ViewID=047E6BE3-6D87-4130-8424-D8E4E9ED6C2A&RenderLoc=0&FlexDataID=4636&PageID=1
228 http://thejournal.com/Articles/2014/12/18/Creating-the-Technology-Framework-for-Personalized-Learning.aspx?Page=2
229 http://www.washingtonpost.com/local/education/stem/schools-move-toward-bring-your-own-device-practices-to-boost-student-tech-use/2014/09/14/4d1e3232-393e-11e4-9c9f-ebb47272e40e_story.html
230 http://www.insight.com/insighton/education/the-great-k12-debate-engaging-students-one-to-one-byod-initiatives/
231 http://www.theage.com.au/national/education/byod-brings-its-own-challenges-for-schools-and-students-20150208-135p08.html
232 http://cambsth.vic.edu.au/page/216/1:1-BYOD-iPad-Program
233 http://thejournal.com/articles/2014/04/30/the-maker-movement-conquers-the-classroom.aspx
234 http://makerfaire.com/maker-movement/
235 http://makerfaire.com/makerfairehistory/
236 http://makezine.com/2013/05/22/the-difference-between-hackerspaces-makerspaces-techshops-and-fablabs/
237 http://www.makerbot.com/
238 https://www.youtube.com/watch?v=7wHorfRvvcE
239 http://selamtamagazine.com/stories/made-china-20
240 http://www.makery.info/en/2015/02/10/le-garagem-un-fablab-bresilien-en-mode-start-up/
241 http://www.theatlantic.com/technology/archive/2015/04/makerspaces-are-remaking-local-economies/390807/
242 http://opensource.com/education/14/5/mobile-library-fab-lab-brings-new-skills-rural-areas
243 http://www.greenwichtime.com/local/article/School-libraries-not-what-they-used-to-be-6054503.php
244 http://www.gardenstreetacademy.org/8th-grade-raises-400-sb-foodbank-wounded-warrior-project/
245 http://www.betaboston.com/news/2015/03/04/anything-is-possible-a-look-inside-kendall-squares-newest-maker-space/
246 http://www.businesswire.com/news/home/20150305005122/en/Project-Opens-Makerspace-Student-Entrepreneurs#.VWyveKakXQQ
247 https://www.idin.org/blog-news-events/news/idin-grantees-five-countries-explore-unique-maker-space-approaches
248 http://3dprint.com/25587/happy-feet-3d-printed-shoes/
249 http://fablearn.stanford.edu/fellows/blog/feet-fleas-and-3d-printing
250 http://3dprinting.com/what-is-3d-printing/
251 http://www.siliconhillsnews.com/2014/08/13/the-pioneers-of-3d-printing-an-industry-invented-at-ut-in-austin/
252 http://newsoffice.mit.edu/2011/3d-printing-0914
253 http://www.canalys.com/newsroom/3d-printing-market-grow-us162-billion-2018
254 http://www.unido.org/news/press/exploring-advanced-t.html
255 http://www.autodesk.com/products/inventor/overview
256 http://3dprinting.com/what-is-3d-printing/
257 http://www.inf.ethz.ch/news-and-events/spotlights/mobile_3dscanner.html
258 http://www.theverge.com/2015/4/5/8347735/this-new-camera-sensor-could-turn-your-phone-into-a-3d-scanner
259 http://www.thingiverse.com/
260 http://meshlab.sourceforge.net/
261 http://www.makerbot.com/
262 http://reprap.org/
263 http://3dprint.com/27743/3d-printing-benefits-schools/
264 http://www.usnews.com/education/blogs/high-school-notes/2014/07/21/3-d-printing-becomes-accessible-for-high-school-teachers
265 https://www.makersempire.com/blog/the-scots-college-first-in-nsw-to-use-makers-empires-learning-program/
266 http://www.techlearning.com/blogentry/9200
267 http://3dprint.com/56699/china-3d-printers-schools/
268 http://educationgrowthadvisors.com/gatesfoundation
269 http://www.nmc.org/publication/nmc-horizon-report-2015-higher-education-edition/
270 http://www.hanoverresearch.com/insights/classroom-evolutions-the-benefits-implications-and-implementation-of-personalized-learning/?i=k-12-education
271 http://ceur-ws.org/Vol-924/paper17.pdf (PDF)
272 http://www.extremenetworks.com/one-size-doesnt-fit-all-a-case-for-adaptive-learning
273 http://www.newyorker.com/tech/elements/will-computers-ever-replace-teachers
274 http://www.christenseninstitute.org/computers-enable-good-teachers/
275 http://educationgrowthadvisors.com/gatesfoundation
276 http://www.dreambox.com/
277 http://www.aleks.com/
278 http://realizeitlearning.com/educational-institutions/institution/
279 http://www.knewton.com/press-releases/sanoma-knewton-bring-adaptive-learning-solutions-k-12-classrooms-across-europe/
280 http://www.edukwest.com/edbrief-mcgraw-hill-education-and-cerego-partner-for-adaptive-language-learning/
281 http://snapwiz.com/wp-content/uploads/2014/03/DVx_Adaptive_Learning_White_Paper.pdf (PDF)
282 http://www.reuters.com/article/2015/01/12/umeworld-limited-idUSnBw125417a+100+BSW20150112
283 http://www.marketwatch.com/story/umeworld-completes-major-expansion-program-for-umfun-k12-adaptive-learning-platform-2014-12-16
284 http://hechingerreport.org/happens-computers-not-teachers-pick-students-learn/
285 http://www.mobymax.com/
286 http://www.emergingedtech.com/2015/03/moby-max-individualized-adaptive-learning-grades-k-8/
287 http://www.emergingedtech.com/2014/01/8-exciting-technology-enhanced-teaching-and-learning-approaches-that-teachers-are-embracing-in-2014/
288 http://www.futuristspeaker.com/2013/02/micro-credits-a-tool-for-self-organizing-the-complex-world-of-education/
289 http://openbadges.org/about/
290 http://hechingerreport.org/what-can-we-learn-from-the-badging-movement/
291 http://openbadges.org/
292 http://www.badgealliance.org/about/
293 http://www.badgealliance.org/working-groups/
294 http://www.alicekeeler.com/teachertech/2014/12/23/badges-and-intrinsic-motivation/
295 https://carlacasilli.wordpress.com/2015/03/15/open-badge-opticks-the-prismatic-value-of-badges/
296 http://erinknight.com/post/54677363396/why-the-chicago-badges-work-matters
297 http://www.chicagosummeroflearning.org/about
298 http://openbadges.tumblr.com/post/64106438071/csol-and-beyond-reflections-on-the-chicago-summer
299 http://openbadges.tumblr.com/post/83654776906/open-badges-research-badge-system-design-call
300 http://www.learningtimes.com/what-we-do/badges/digit-badges-nycdoe/

301 http://collegeready.gatesfoundation.org/article/new-jersey-digital-badging-sparks-professional-learning
302 http://time.com/3818184/the-next-experiment-in-education/?p=3818184?xid=tcoshare
303 http://v2014.my-europa.eu/index.php?option=com_community&view=groups&task=viewgroup&groupid=458&Itemid=504
304 http://remakelearning.org/blog/2014/08/26/why-grit-and-perseverance-may-be-just-as-important-as-stem-skills/
305 https://www.oculus.com/
306 http://www.wired.com/2014/12/the-hype-cycle-whats-next-for-google-glass/
307 http://quantifiedself.com/
308 http://en.wikipedia.org/wiki/Wearable_computer
309 http://www.ce.org/News/News-Releases/Press-Releases/2014/Record-Breaking-Year-Ahead-CEA-Reports-Industry-Re.aspx
310 https://deviceatlas.com/blog/targeting-wearable-devices
311 http://www.cbsnews.com/news/wearable-gps-tracking-for-children-to-ease-parents-minds/
312 http://www.mintpressnews.com/mintpress-investigates-school-districts-using-gps-ankle-bracelets-smartphone-tracking-on-truant-kids/197360/
313 http://www.fitbit.com
314 https://jawbone.com/up
315 http://www.learningliftoff.com/do-kids-need-wearable-technology/#.VSWUczvF87M
316 http://www.leapfrog.com/en-us/products/leapband
317 https://www.sqord.com/
318 http://www.educationworld.com/a_news/teacher-how-gopro-got-my-students-excited-learn-1937487050
319 http://www.dramafever.com/news/japanese-high-school-students-design-wearable-tech-youll-actually-want-to-wear/
320 http://www.voanews.com/content/apple-set-to-unveil-new-smartwatch/2673159.html
321 http://chronicle.com/blogs/wiredcampus/apple-watch-coming-to-a-classroom-near-you/54449
322 http://tafeqld.edu.au/about-us/TELLS/
323 http://www.jnxyz.education/wear2learn/2014/9/29/is-this-the-worlds-1st-apple-watch-classroom-trial
324 http://www.edutopia.org/discussion/apple-watch-cupertinos-non-starter-education
325 http://www.starkey.com/
326 http://users.ece.gatech.edu/mghovan/index_files/TongueDrive.htm

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T 512-445-4200
F 512-445-4205
E communications@nmc.org

nmc.org

1250 Capital of Texas Hwy South
Building 3, Suite 400
Austin, TX 78746