NMC Horizon Project

R&E Networks: Pathways to Innovation for K-12

An NMC Horizon Project / Internet2 Strategic Brief

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Executive Summary

The purpose of this NMC Horizon Project Strategic Brief is to assist the K-12 community and policymakers in advocating for high-quality, high-capacity, and affordable broadband connections to every classroom in the United States. It reflects the results of a May 2015 convening of national educational technology experts on the issue of high-speed networking in K-12 education. In their discussions, a panel of experts representing a range of leadership roles across the US K-12 education system identified trends within and beyond schools that are currently — and have the potential to be — enabled and constrained not just by inadequate bandwidth, but also by a lack of connectivity to potentially transformative Research and Education (R&E) networks. During this process, the experts considered a range of recently published research, policy reports, and popular media.

R&E networks are currently being leveraged in exciting projects in which K-12 students are connecting with peers around the world to discuss and debate pressing social issues, operate sophisticated scientific instruments remotely, stream high-quality educational videos, engage in immersive simulations, and virtually experience the resources of presidential libraries and national parks. These exemplars illustrate what is possible if the R&E network community expands to include more K-12 schools and districts.

Potential applications are not limited to the activities that are underway today. The panel of experts determined R&E networks to be essential in scaling online and flipped learning paradigms, student data analysis, cloud computing, Bring Your Own Device (BYOD) models, and other emerging practices.

One theme was clear from experts' discussion of infusing high-speed networking in K-12: there is an immediate need to embrace R&E networks' robust advanced networking infrastructure. The group recommends that education leaders get involved in and promote the R&E network community as a viable, affordable, and accessible means to transform teaching and learning.

The New Media Consortium *(NMC) is a community of hundreds of leading universities, colleges, museums, libraries, schools, and research centers. The NMC stimulates and furthers the exploration and use of new media and technologies for learning and creative expression. The NMC's series of Horizon Reports, Technology Outlooks, and Strategic Briefs are used in more than 190 countries by millions of educators and education leaders.*

About Internet2

Internet2® is a member-owned advanced technology community founded by the nation's leading higher education institutions in 1996. Internet2 provides a collaborative environment for US research and education organizations to solve common technology challenges, and to develop innovative solutions in support of their educational, research, and community service missions.

Internet2 also operates the nation's largest and fastest, coast-to-coast research and education network, with the Internet2 Network Operations Center powered by Indiana University. Internet2 serves more than 90,000 community anchor institutions, 290 US universities, 70 government agencies, 43 regional and state education networks, 84 leading corporations working with our community, and more than 65 national research and education networking partners representing more than 100 countries.

Introduction

The impetus for this report is the changing policy landscape around digital learning in K-12 schools. Not all American classrooms are connected to broadband — always-on, high-speed Internet access, that keeps pace with the evolving learning needs of students.[1] Policymakers are attempting to implement digital learning and broadband-related solutions through programs such as the White House *ConnectED Initiative*. *ConnectEd* is designed to connect 99% of K-12 schools via high-speed networking, increase use of funds and resources for high-speed educational applications, and improve teacher training by 2018.[2]

The US Department of Education's *#FutureReady* initiative calls upon superintendents and other education stakeholders to transition to digital instruction. Despite these extant programs, a digital divide persists between those with and without access to ultra high-speed and high-quality Internet. This not only affects students' learning opportunities, but also stymies pedagogical innovation, digital learning scaling, and data-driven decision making.[3] Many stakeholders hope the Federal Communications Commission's new E-Rate rules will help to advance schools' adoption of higher bandwidth and quality broadband.

To explore the nature of this divide, in May 2015, the New Media Consortium (NMC) and Internet2 engaged in an unprecedented partnership to explore ways in which the Research and Education (R&E) network community can support and enhance primary and secondary teaching and learning. Internet2 is a 501(c)(3) not-for-profit member-owned advanced technology community founded by the nation's leading higher education institutions in 1996. It played a seminal role in the creation of the modern Internet and the applications that have made it one of the most transformative technologies of our time. The NMC, a 501(c)(3) not-for-profit educational technology research organization, led the project, based on the approaches used in its influential work across the world through the highly-regarded *NMC Horizon Report* series.

The NMC and Internet2 research and analysis process had several components. The first was to survey scholarly and professional literature, as well as other sources of credible information, to detail 1) important trends and innovations in education that are enabled by or have the potential to be enhanced by high-speed, advanced networking; and 2) the major challenges facing K-12 stakeholders that can be addressed with the use of high-speed networking. In the second phase of work, a panel of 42 nationally renowned experts was convened to engage in a comprehensive dialogue about the most critical ideas that the NMC research had revealed. The resulting work, which could be described as the "collected wisdom" of experts, was used as the basis for the NMC and Internet2 collaborative research team's analysis, the results of which are detailed in this report.

The goal of this report is to document opportunities, challenges, and recommendations for K-12 stakeholders to consider as they address the demands of digital learning. In this report, we present an overview of R&E networking and some exemplary teaching and learning applications that these networks are uniquely positioned to deliver to classrooms nationwide. Then, we include a synthesis of the results from our expert panel and finally, conclude with expert-informed recommendations for action. As will be clear from the recommendations that follow, education stakeholders must look for opportunities to potentially act upon quickly, as well as catalyze discussions to redefine the common understanding.

Research & Education Networks and Innovation

Overview

Teaching, learning, and research have the potential to be infused and transformed by myriad Internet-based applications, ranging from streaming video to big data analysis to cloud storage. These uses demand both the high-speed and high-quality bandwidth available through the advanced R&E networking community.

Internet2 operates the nation's fastest and most advanced, coast-to-coast R&E network and, in conjunction with 43 R&E networks across the US, serves more than 90,000 K-12 schools, public libraries and other community anchor institutions, along with 290 US universities and 70 government agencies. Additionally, the reach of the Internet2 Network is broadened by connections to more than 65 national research and education networking partners across more than 100 countries.

The United States Unified Community Anchor Network (US UCAN) is a national program within Internet2 that works with regional R&E networks across the country to connect national and local community anchor institutions (CAIs), including schools, libraries, healthcare facilities, and other public institutions, to advanced broadband capabilities. Internet2's K20 Initiative is part of the US UCAN program and provides a convening point for Internet2 member institutions and innovators from schools, colleges and universities, libraries, and museums to collaborate around the uses of advanced networking-enabled technologies, applications, middleware, and content.

R&E networks, like the ones operated by Internet2 and its regional partners, are uniquely designed and engineered to meet the needs of some of the most demanding Internet users in the country, namely scientists, academics, and researchers. R&E networks were built to offer bandwidth with unparalleled quality, speed, and operational transparency. As digital learning becomes more routine in K-12, R&E networks are uniquely capable of supporting advanced, broadband-enabled teaching and learning applications today and in the future.

US UCAN and K20 Initiative at-a-Glance

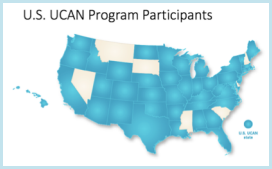
US UCAN Mission:
Support the advanced networking and applications needs of national and local community anchor institutions (CAIs), and integrate these anchors into the research and education community.

A key part of US UCAN is the K20 Initiative, whose mission is to focus on K-12 schools, community colleges, museums, and libraries to promote collaboration with the research and education community.

K20 Initiative Goals:

- Bring all levels of educational innovators into appropriate regional, national, and international advanced networking efforts.
- Encourage and help sustain education, private sector, and government partnerships.
- Enhance teaching and learning by exploring advanced network applications, services, tools, and digital content.
- Enable quick, pervasive technology diffusion.

Estimated 93,410 CAIs in 43 states:



- 84,456 K-12 Schools
- 4,227 Public Libraries
- 1,491 Colleges & Universities
- 799 Community or Vocational Colleges
- 2,237 Health Care Organizations
- 200 Museums, Science Centers, Zoos & Aquariums

While many Internet applications simply require abundant bandwidth, the R&E community also recognizes that many advanced applications require high-quality bandwidth, such as maximum packet delay (latency) guarantees consistent, symmetrical bandwidth, and predictable and efficient paths for network traffic. For example, remote collaborative applications require very specific latency and visual jitter levels,

particularly with respect to video-casting the performing arts and operating remotely controlled scientific instruments. The Internet2 network optimizes its paths to bring latency as close to the speed of light as possible, assuring that high-performance applications can work at the maximum distance between collaborators. For students, access to high-performance networks could help to quickly ignite and sustain interest in an interactive educational experience. Traditional best-effort services available on the "commodity" Internet are not always capable of meeting the needs of these advanced applications and the students they serve.

Since its inception in 1996, the Internet2 community has enabled users to be deeply involved in the service design and operational processes of the network, and strived to make network operations as transparent as possible. These guiding principles have enabled R&E networks to more effectively anticipate and meet user requirements rather than react to emerging demands. This open, transparent architectural approach, where users are able to examine R&E network operations on a broad scale and troubleshoot across networks which are often controlled by or under the purview of different, but partner, organizations, has contributed to the high network performance levels experienced by connected institutions.

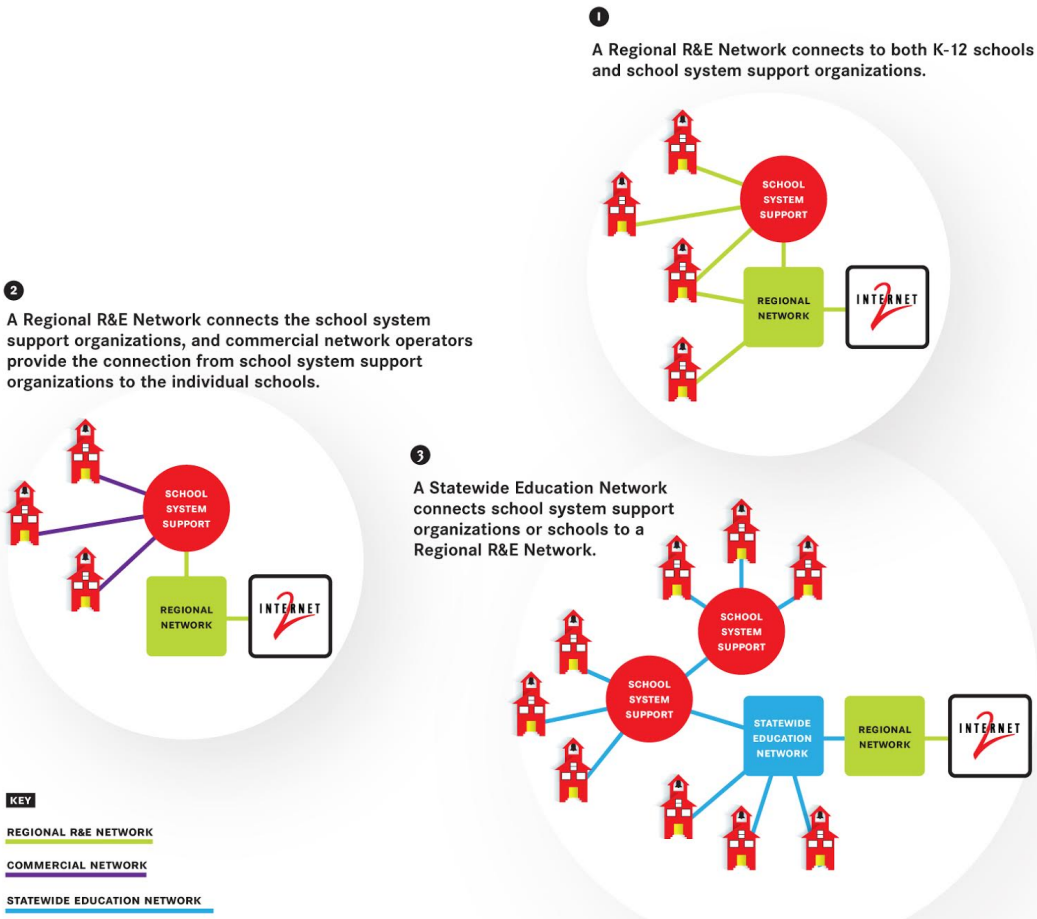
R&E network organizations share a depth of technical, operational, and procurement knowledge along with several other key organizational characteristics. The vast majority are operated as not-for-profits with public service missions designed to further some combination of research, education, medical, and economic development aims. Of course, the specific organizational structures differ as some R&E networks are operated as projects of universities, some are run under the auspices of state government agencies, and others are set up as fully independent, non-profit organizations.

Beyond network services, many R&E networks are increasingly offering additional value-added services that leverage the underlying advanced networking infrastructure such as disaster recovery, email and web server hosting, high-definition (HD) videoconferencing services, and a growing range of cloud-hosted services like compute cycles, applications, and storage. By aggregating demand, they are able to lower the prices for these services to everyone on the network.

As the figure on the next page illustrates, connecting to an R&E network is easy for schools. Connections can be established at both the district level as well as at individual school buildings through regional R&E networks. Another option is for a state R&E network to provide service or work with a regional R&E network and/or commercial provider.

Regardless of the blend of providers used, schools connected to their local R&E network receive more than connectivity services. They become part of a diverse and thriving community of practice offering access for K-12 students, teachers, administrators, and technical support staff to a wealth of experiences and expertise not as readily available to schools that are not connected via the R&E networking community.[4]

Fig. 1: Connecting to a Regional R&E Network



K-12 Innovation with R&E Networking: Exemplars

The Internet2 K-20 community enhances teaching and learning through advanced network applications, services, tools, and digital content to extend access to innovative educational opportunities and resources. Advanced networks enable quick, pervasive technology diffusion and most importantly, provide high-quality experiences.

R&E networks host a variety of innovative learning opportunities using streaming media, digital collections, videoconferencing, educational gaming, immersive environments, remote instrumentation, webcam presentations, and classroom collaboration. Below are a few examples of Internet2's K-20 community participation to bolster education innovation.

Streaming media has been positioned as one of the most exciting and impactful learning technologies available, but its use is often hampered by bandwidth limitations that prevent simultaneous and spontaneous use.[5] Streaming media services for K-12 have been cited as containing older material that does not display high-quality video.[6] However, when adequate bandwidth is coupled with smart management strategies like caching, HD display, and better descriptions that enables targeted selection, the benefits of video multiply.[7]

NJVID, an established and active member of the Internet2 community, promotes the use of streaming media through its state-of-the-art digital media repository service for streaming and preservation of academic and research media for higher education.[8] By providing cost effective media streaming and repository services, NJVID enables higher education institutions to overcome the technical barriers in digitizing and making media available to users through a secure portal. To date, the K-12 community lacks a similar portal in extent and purpose; spreading greater awareness of the ways in which R&E networking can enable streaming media use in K-12 can address this gap.

Interactive Videoconferencing. The Internet2 community also partners with the diverse community of R&E-connected organizations to help expose schools to the benefits of videoconferencing. While videoconference use in higher education and business is increasing, the user experience varies greatly depending on available bandwidth and the quality of the encoded video. User demand for higher-quality videoconferencing experiences, as well as evolving video standards like HD, 3D, and 4K, are requiring even more bandwidth.[9]

For schools, limitations to videoconferencing not only stem from bandwidth-related constraints, but also from a seeming lack of age and curriculum appropriate opportunities. The Presidential Primary Sources Project (PPSP) is a collaborative program sponsored by the National Park Service, US Presidential Libraries and Museums, and the Internet2 community. The goal of the annual project is to enable presidential historians and National Park Service Rangers to engage in discussions with classrooms throughout the national and international education community around an overarching learning standards-aligned topical theme, using primary source documents to inform the discussion. For example, during the 2014 PPSP program series, students explored how various US Presidents have influenced civil and human rights throughout history.

Real time classroom collaboration is an early Internet-enabled development with roots in the first distance learning efforts. As the speed, reliability, and efficiency of classroom Internet access has

improved, the accessibility and reduced cost to real time videoconferencing has been possible for many educators.[10]

However, barriers relating to network bottlenecks, videoconferencing system interoperability, lack of the necessary video hardware and software, and inability to scale up for large user sets have prevented widespread implementation. With the use of R&E network bandwidth, many of these obstacles abate, and compelling video-enabled classroom collaborations with remotely located instructors and students are possible. Since 2012, a team of K-12 collaborators led by NYSERNET,[11] the R&E network in New York, has used the global connectivity of R&E networks to host students from Australia, Canada, Croatia, Czech Republic, Hong Kong, Iran, Russia, Taiwan, Ukraine, the United Kingdom, and the United States to engage in debates about the best way to meet the world's growing energy needs. This global R&E networking infrastructure not only affords students the opportunity to interact and share in real time about pressing international issues, but also helps break down cultural barriers and promote understanding.[12]

Remotely controlled online laboratories are experimental facilities that can be accessed through the Internet, allowing students and educators to carry out experiments from anywhere, anytime. The ability to remotely control scientific instruments in online laboratories has been attractive to K-20 educators for the last two decades. However, widespread adoption of this activity has been limited by school technology that prohibits simultaneous use and discourages scientists to share their resources.[13] An R&E network allows learners and scientists to connect and alleviates many of those concerns. iLabCentral hosts a growing range of remotely-accessible real laboratories that can greatly expand the range of science and engineering experiments available to students. The iLab vision is to disseminate lab experiments as broadly as possible by making it easier for faculty to share their labs.[14]

Finding appropriate remote instrumentation and interactive learning opportunities is seamless with North American Network of Science Labs Online (NANSLO), an international consortium that enables access to high-quality, modular, and openly-licensed courseware, integrating web-based labs with software, video, and robotics.[15] NANSLO currently has three nodes where remote science labs are hosted: Colorado, Montana, and British Columbia. All institutions leveraging NANSLO lab activities have access to the NANSLO Scheduling System, enabling faculty and students to access the labs through an intuitive, automated process.

These exemplars provide a glimpse at the ways in which R&E networks and their partners can transform teaching and learning through their tools, applications, and communities. In an advanced network-enabled, high-speed bandwidth environment, the possibilities are only limited by imagination — not by connectivity.

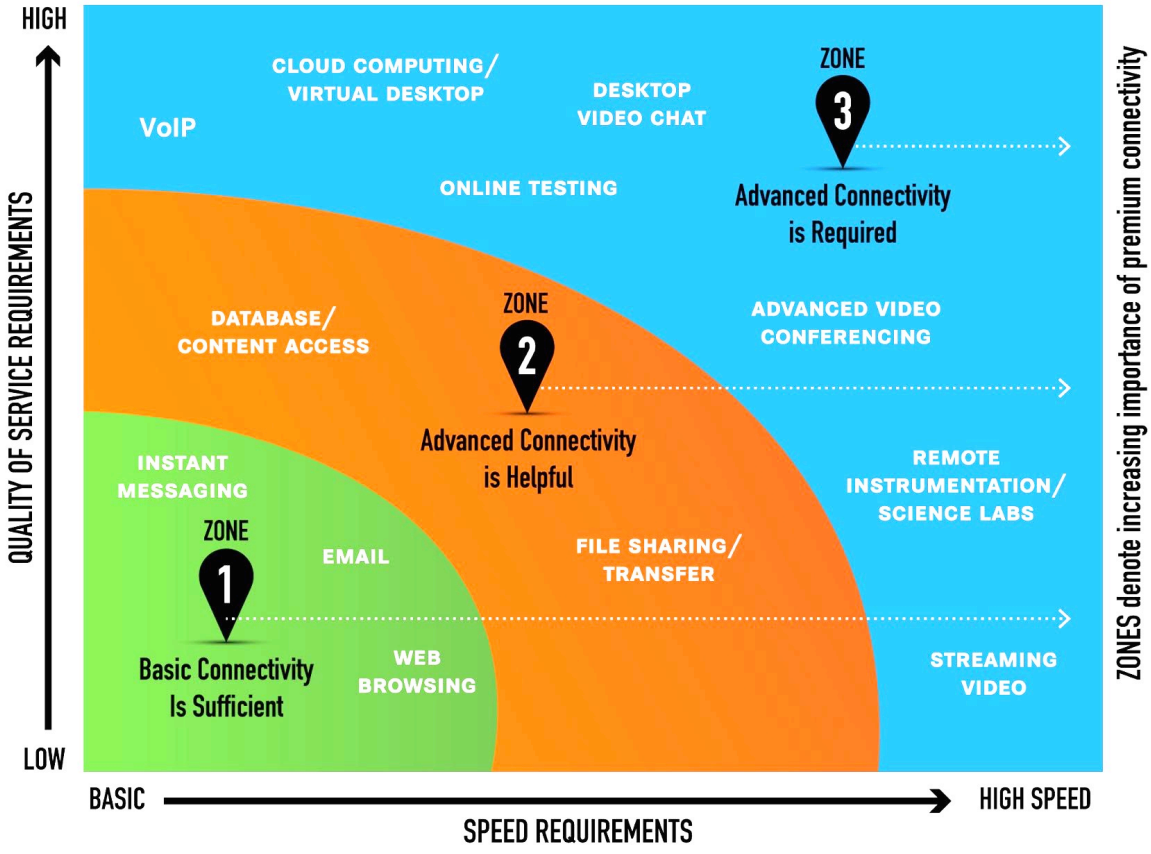
Advanced R&E Networking in K-12: Experts' Views

Despite the promising example uses of ultra high-speed bandwidth in education, the K-12 community has not fully engaged the possibilities offered by R&E networks. Although about 60% of US K-12 schools (public, private, and charter) access Internet2 via an R&E network, often with a commercial carrier providing some connectivity support, the connection to R&E networks is only as capable as the last mile connection, or "on-ramp" for the school.

In the State Educational Technology Directors Association's (SETDA) 2008 report *High-Speed Broadband Access for All Kids: Breaking Through the Barriers*,[16] national education leaders reported that ubiquitous access to high-speed broadband should be considered as vital a component of K-12 school infrastructure as electricity, air conditioning, and heating. In May 2012, SETDA followed up with *The Broadband Imperative: Recommendations to Address K-12 Education Infrastructure Needs* in which the authors reported that the availability of adequate bandwidth remained piecemeal in schools, and they recommended targets for bandwidth per student.[17]

In May 2015, NMC and Internet2 leaders convened a panel of 42 K-12 experts to capture their views of the challenges and opportunities that can be addressed by ultra high-speed, high-quality bandwidth, as well as descriptions of the technological developments gaining prominence in schools that may be further enabled by robust bandwidth. Figure 2 illustrates the types of activities enabled and/or enhanced by ultra high-speed bandwidth.[18]

Fig. 2: Quality of Service and Speed Requirements of Example Applications



As Figure 2 shows, many commonplace educational activities such as email and web browsing work well with basic connectivity; however, when learners engage in sophisticated activities like simulations and bandwidth-intensive activities like video streaming, advanced connectivity is critical.

The next section reveals the experts' views of key developments in technology, trends, and challenges that can be supported and furthered by the advanced connectivity available through R&E networks.

Developments in Technology

The expert panel began their discussion by sharing technologies and digital strategies that they felt were important for near-, mid-, and long-term educational transformation. The experts focused on developments that would empower students to control their own learning and to access opportunities to engage with content anytime, anywhere. Bring Your Own Device (BYOD) was a dominant topic of the discussion because the movement is gaining popularity in many schools as a way of increasing access to technology without the cost of schools purchasing a device for each student. BYOD allows students to bring their personal laptops, tablets, and smartphones from home and use them for educational applications in the classroom; students' participation is streamlined by using a device with which they are already familiar.[19]

At a time when budgets are shrinking, for many districts, one laptop per student (1:1) initiatives require unsustainable investments in support, replacement, and associate costs. A growing number of school districts consider BYOD a promising alternative to integrate cost-effective technology into their educational programs.[20] However, BYOD programs have been met with some concerns from educators who believe that while BYOD solves device availability for some students, these programs do little to alleviate the impacts of inadequate bandwidth and network infrastructure.[21]

Over time, we will continue to see a shift to cloud-based services. Ultimately, only the largest institutions will be able to justify special use projects in local data centers. This means that the bandwidth must be wide, reliable, and redundant.

Kevin Schwartz
Clear Creek ISD

BYOD is closely related to a number of other key technologies suggested by our expert panel. The wide availability of cloud computing, including services, content, and applications, is enabling more schools to adopt BYOD policies and introduce mobile devices in the classroom.[22] As cloud applications and storage consume larger proportions of school districts' technology budgets, the experts raised data stability, security, and persistence concerns.[23]

The experts also shared their opinions about BYOD and cloud computing in the context of online learning and the flipped classroom. Online learning can take place in a fully synchronous, asynchronous, or hybrid online format and is gaining popularity in K-12 for credit recovery, credit forward, course diversification, and informal learning. The flipped classroom makes use of online learning tools and resources to shift valuable class time to devote to more active, project-based learning where students work together to gain a deeper understanding of the subject. Rather than the instructor using class time to dispense information, students watch video lectures, listen to podcasts, peruse enhanced e-book content, or collaborate with peers in online communities any time before or after class. Students thus manage the content they use, the pace and style of learning, and

the ways in which they demonstrate their knowledge; the instructor adapts instructional and collaborative approaches to suit their personal learning needs and journeys.

Additionally, the panel centered its discussion on technology tools presently available to the K-12 education sector, but that have varying levels of adoption based on a number of institutional, technological, and financial challenges. As the experts turned their attention to trends and challenges relating to K-12 high-speed networking, it was clear that they considered the availability and use of high-speed networking as a necessary component of scaling the technologies they saw as gaining importance in schools.

Trends and Challenges Driving Demand for Bandwidth

In isolation, inadequate bandwidth is not an educational crisis; however, when bandwidth drives what is taught and learned in K-12 education, its availability becomes pivotal. Current research and literature about K-12 education reflects a focused movement to reinvent the traditional classroom paradigm and rearrange the entire school experience through innovative learning approaches. Methods such as project- and problem-based learning call for school structures that enable students to move organically from one learning activity to another, removing the limitations of the traditional structured school day.[24] Fluid and student-centered activities are enabled by ubiquitous and reliable Internet access to support learning personalization; use of student-preferred devices; a blend of hybrid, online, and in-person coursework; cloud storage; and a flipped classroom — all available 24 hours a day, seven days a week.[25]

As technologies such as tablets and smartphones are more readily accepted in schools, educators are leveraging these tools in active learning approaches, allowing students to take control of how they engage with a subject and to brainstorm and provide solutions to pressing real life issues.[26] However, more technology integration will demand a seamless, reliable technological infrastructure, including bandwidth adequate to support and scale learning innovations. Once educators are able to embrace and institutionalize current learning technologies, they will have the confidence and vision to further evolve teaching and learning.

Contextualizing learning to make it more meaningful for the students. Instead of requiring students to learn abstract concepts, we will be contextualizing it with mobile learning and wearable technologies.

Helen Crompton
Old Dominion University

Expanding equity and access. New models of education are bringing unprecedented options to schools, especially for students whose needs are not being well served by the current system. Most US states also offer and encourage K-12 enrollment in online courses, and some states even require K-12 students to complete online coursework in order to graduate. Further, much of the standards testing is online — creating a tremendous bandwidth demand on school netwoks. Adding to the need for diverse course options is the fact that many students do not formally attend either type of school. The National Center for Education Statistics (NCES) reported that over 3% of the school-age population was homeschooled during the 2010-11 school year.[27] For school leaders and policymakers, the challenge is to offer high-quality choices to students who need them. As alternatives to traditional schooling gain popularity, there is a growing need to determine how to best support at scale online collaboration, interaction, deep learning experiences, and assessment in K-12 — for both home and classroom learning environments.

Personalizing learning. Personalized learning includes a wide variety of approaches for self-directed and group-based learning that can be designed around each learner's goals.[28] There are two paths of development for personalized learning: the first is organized by and for the learner, which includes students' choice of apps, social media, and related software. School goals and interests drive the other path, primarily in the form of adaptive learning. In this pathway, which envisions the development of tools and data streams that are still some time away from being seen in schools, adaptive learning is enabled by intervention-focused machine intelligence that interprets data about how a student is learning and responds by changing the learning environment based on their needs. Adaptive learning personalization depends on ready and reliable access to student data to determine students' areas of mastery and need. While the concept of personalized learning is fairly fluid, it is becoming more and more clear that it is individualized by design, different from person to person, and built around a vision of life-long learning. [29] Student-centered, technology-driven instruction remains elusive for many schools because one or more pieces of the equation are missing, particularly robust, ubiquitous connectivity.

By using the Internet for research and a makerspace for building, students do ambitious projects with plenty of real-world trial and error. This develops a grounding in physical activities, a framework for understanding how to apply science and technology, and foster many of the currently valued non-cognitive attributes such as grit, growth mindset, perseverance, systems thinking, design thinking, etc.

Marie Bjerede
e-Mergents

The makerspace movement exemplifies personalized learning, as identified by the experts. In makerspaces, educators, learners, and often parents or community members come together to experiment or create novel technologies and solutions.[30] Aside from the bandwidth requirements of makerspace equipment such as 3D printers, the growing number of student- and teacher-created digital artifacts and learning resources will need to be curated and preserved over time. R&E networks can support 3D imaging, cloud storage, and on-demand viewing. Makerspaces also frequently make use of expertise from outside the school for tutoring or lectures for student projects. These sessions will cross geopolitical borders and require students to have ready access to high-speed networks to collaborate with and stream content from global experts.[31]

Whether through games, videoconferencing, or other forms of immersive collaboration, educators need to be thinking beyond the walls of school to bring specialists, authors, other teachers, and peers into their learning processes to help students solve real-world problems.[32] The international reach of the R&E networking community gives K-12 educators ready access to resources and solutions that can be delivered with real time, unimpeded access.

Using student data to understand learning. Education is engaging with data science with the aim of learner profiling, a process of gathering and analyzing large amounts of detail about individual student interactions in online learning activities.[33] The goal is to build and foster personalized and adaptive learning through better pedagogies, empower students to take an active, formative role in their learning, target at-risk student populations, and assess factors affecting completion and student success. For learners, educators, and researchers, learning analytics, a key technology identified by the panel, is already starting to provide crucial insights into student progress and interaction with online texts, courseware, and learning environments used to deliver instruction. Data-driven learning and

assessment will build on those early efforts. Myriad technical, financial, legal, and political realities of collaboration around student data prevent real progress. Currently, several state initiatives are starting to take hold that enable cross-school collaboration, and increasingly, some institutions are joining together to combine resources for data-driven decision-making.

Safety of student data has long been a concern in K-12 education, which is evident in legislation that has been passed to safeguard students and their personal data, such as the federal Family Educational Rights and Privacy Act (FERPA).[34] As schools embrace technology and more learning takes place online and in 1:1 settings, education leaders see great potential to leverage these digital learning environments to mine data, which can be used to decipher trends in student behavior and create personalized software. Schools around the world are adopting cloud computing to support adaptive learning, promote cost-savings, and encourage collaboration, but sometimes the safety of student data is threatened when third-party vendors provide low-cost software as a service in return for access to student data that they then profit from.

R&E networks can provide a variety of cloud-based services and storage for large-scale data sets and single sign-on secure access to data through the InCommon platform and suite of services.[35] For example, Shibboleth is a standards-based, open source software package for Web single sign-on across or within organizational boundaries.[36] It allows sites to make informed authorization decisions for individual access of protected online resources in a privacy-preserving manner. More than 500 higher education organizations leverage InCommon to support their federated identity management needs.

Although the most difficult barriers to digital transformation are human, many solutions can be enabled with a robust infrastructure that supports new ways of teaching and learning. A school's technology infrastructure must be scalable and future-resilient. Technology innovation needs to be essentially "invisible" to the instructional experience, thus reducing the barriers to adoption to human ones that can be overcome with cultural evolution and organizational leadership.

Recommendations for Fostering Educational Innovation

This report reviews the structure and function of ultra high-speed R&E networks in the United States, with a closer look at the Internet2 community and its efforts to foster innovation in K-12 education. The key educational trends identified by the panel of experts can benefit from or be enabled by R&E networks. The experts also shared challenges in K-12 education that they knew or felt were addressed by high-speed bandwidth. In this section, recommendations are provided for federal, state, and local education policymakers as well as to K-20 community members to further the potential R&E networking has for K-12 education innovation.

Recommendation 1: Connect to an R&E Network

Despite the many efforts currently underway to increase school broadband and technology use in education, a range of logistical issues have prevented many schools from adopting many of these services. As a result, broadband adoption rates in schools and classrooms, on a national level, remain fragmented and average per-student bandwidth remains low.[37]

As demonstrated in this report, R&E networks offer many advantages to K-12 schools. The first step to taking advantage of these benefits is to find a local R&E network provider. The table on the next page lists providers for each state that participate in the R&E network community. Providers will help determine which of the accessibility and related configurations, depicted in the graphic on page 5, fits a school's particular needs and requirements.

EdTech planners must face the reality that estimating the amount of bandwidth to support networked digital education requires an affordable, scalable, extensible, nimble, and accessible set of network providers because they never really know what is in front of them.

Mike Abbiatti
WICHE

Once the provider and plan is on board, it will be time to finance the investment. As described earlier, in many instances, R&E network subscription costs are lower or equal to those of commodity Internet connections when all of the "value added" services are factored. Assistance may even be available. Many schools have been frustrated in their attempts to receive federal assistance for their Internet connections through complicated E-rate program application procedures.[38] Even when schools were successful in navigating the complexities of E-rate, it was not always clear that connections to R&E networks were allowable expenses.

However, in the last five years, the FCC released sweeping changes to the E-rate program, including focusing investment on broadband and wireless networking, as well as simplifying the application process. Furthermore, new E-rate policies have built-in incentives to help states with aggregating demand and supporting R&E networks.[39] Potential subscribers should contact their state libraries, department of education, and R&E network providers to learn more about applying for E-rate funds.

Get Connected! Contact these regional R&E networks to find out if your organization is connected! Find the most recent list of providers at http://k20.internet2.edu/get-connected.

Table 1. R&E Network Providers by State

AL	Alabama Research and Education Network (AREN)	http://www.asc.edu/network/
AR	Arkansas Research and Education Optical Network (ARE-ON)	http://www.areon.net/
AZ	Sun Corridor Network	http://suncorridornet.org/
CA	Corporation for Education Network Initiatives in California (CENIC)	http://www.cenic.org
CO	University Corporation for Atmospheric Research	https://nets.ucar.edu/nets/intro/staff/jcustard/
CT	Connecticut Education Network (CEN)	http://cen.ct.gov
DC	Capital Area Advanced Research and Education Network (CAAREN)	http://www.caaren.org/
FL	Florida LambdaRail	http://www.flrnet.org/
GA	PeachNet	http://www.usg.edu/peachnet
HI	Hawaii Education Network	http://doe.K-12.hi.us/
ID	Idaho Regional Optical Network (IRON)	http://ironforidaho.net/
IL	Illinois Century Network	http://illinois.net
IN	I-Light - Indiana's Optical Network	http://ilight.net
IA	Iowa Communications Network	http://www.icn.state.ia.us/
KS	KanREN, Inc.	http://www.kanren.net/
KY	Kentucky Regional Optical Network - KyRON	http://kyron.ky.gov/
LA	Louisiana Optical Network Initiative (LONI)	http://www.loni.org
ME	NetworkMaine	http://www.networkmaine.net
MD	Maryland Research and Education Network (MDREN)	http://www.mdren.net/
MA	MECnet	http://www.mecnet.net
MI	Merit Network, Inc.	http://merit.edu
MN	Minnesota Statewide Education Group (MSEG)	http://www.ties.K-12.mn.us/Getting_started_with_Internet2.html
MO	MOREnet	http://www.more.net
NE	Network Nebraska	http://www.networknebraska.net
NJ	NJEDge.Net	http://njedge.net
NC	MCNC	http://www.mcnc.org
ND	North Dakota Statewide Technology Access for Government and Education network (STAGEnet)	http://www.stagenet.nd.gov/
NM	New Mexico Council for Higher Education Computing and Communication Services (CHECS)	http://www.checs.net/
NY	NYSERNet	http://nysernet.org
OH	OARnet	http://oar.net
OK	OneNet	http://www.onenet.net/
OR	Network for Education and Research in Oregon (NERO)	http://www.nero.net
PA	KINBER Three Rivers Optical Exchange	http://www.kinber.org/ http://www.3rox.net
RI	OSHEAN (Ocean State Higher Education and Administrative Network)	http://www.oshean.org/
TN	Education Networks of America, Inc. (ENA)	http://www.ena.com
TX	Texas Education Telecommunications Network Lonestar Education And Research Network (LEARN)	http://www.tetn.net http://www.tx-learn.org
UT	Utah Education Network (UEN)	http://www.uen.org/
VA	NetworkVirginia	http://www.networkvirginia.net
VT	Vermont UCAN	http://epscor.w3.uvm.edu/2/node/27
WA	K-20 Education Network	http://www.wa-k20.net/
WI	WiscNet	http://wiscnet.net
WV	West Virginia Network (WVNET)	http://wvnet.edu
WY	University Corporation for Atmospheric Research	https://nets.ucar.edu/nets/intro/staff/jcustard/

Recommendation 2: Make R&E Network-Enabled Teaching and Learning Opportunities Visible

An essential element of any change to teaching and learning involves teacher excitement, readiness, and confidence in changing practice. With R&E networks, education policymakers and administrators have a number of incentive options for enhancing the resources available to reluctant educators and for creating incentives for integrating broadband-enabled technologies into their curricula. For example, school administrators create mechanisms that leverage existing approaches to providing teacher technology training and technical support. Once a school is connected to an R&E network, educators can engage in professional learning communities and other ongoing professional development opportunities. Integrating the technology into the classroom initially for personal enhancement has proven to be successful in encouraging large-scale transfer of new learning approaches to their classrooms.[40]

For many educators, professional learning is the central aspect of how they make decisions about teaching. Even if educators gain the skills to manipulate or operate a particular technology, these skills must be paired with relevant resources. Teaching and learning resources, both physical and human, that support these kinds of learning are customized for specific missions. Digital repositories of lessons, learning resources, and exemplars allow remote access, breaking down the barrier between technology and implementation. To allow teachers and students to take advantage of wider ranges of materials and communicate with people outside of classrooms, these repositories must be specialized to meet the needs of specific communities of learners. In the context of current educational trends, greater use of R&E networks will depend on the existence of a repository of standards-based, user-friendly learning activities that allow students to access resources as well as contribute feedback relating to implementation ideas and suggestions for further use.

This repository can be positioned as a natural complement to the existing K20 community's Muse database of R&E network-enabled projects.[41] Muse allows the public to search for events, interest groups, organizations, people, and projects that make use of R&E networks; the addition of lessons, learning resources, and best practices would allow new members of the R&E networking community to immediately deploy their new connectivity to enhance teaching and learning. School districts can add Muse to their preferred learning resource sites, and metadata from Muse content can be shared with district- and state-wide learning management systems and online repositories.

Recommendation 3: Focus on How the R&E Network Supports Learning

There is a heightened focus on demonstrating learning outcomes for all educational investment. A critical component of spurring greater K-12 participation in the R&E networking community is identifying and sharing the benefits and best practices associated with greater availability of high-speed, advanced network connectivity. Providing this information in a comprehensive yet user-friendly way could engage larger numbers of educators, parents, and researchers to implement methods and applications that capture the effect of bandwidth-rich environments. However, the vast amount of information potentially available, from data depicting how certain technologies impact learning outcomes to statistics about technology usage to a wide array of studies examining digital literacy and social learning, may require community collaboration and interpretation to identify true learning benefits.[42] Stakeholders will need to carefully define their goals for R&E networking, focus their data collection on these activities, and widely share successes and challenges.

Devising a systematic way of processing, organizing, and highlighting important datasets, observations, and conclusions from a host of literature and media produced locally as well as by departments of education, scholarly researchers, and other interested stakeholders will allow for more targeted information about the benefits of R&E networks in educational environments. Aside from providing an entry point into the relationships between ubiquitous high-speed networking and student learning, a concerted effort to distill and coordinate research outcomes can also lead to the emergence of best practices for scaling the use of enhanced connectivity.

School leaders should regularly document the impact of both access to advanced R&E networking infrastructure and the R&E network-enabled communities of practice on teaching and learning: what is working, what is not, and the lessons learned. Because the option of high-speed networking is so new to many schools, determining how this connectivity is fostering educational innovation is particularly critical. These lessons need to be recorded so they can be shared across the organization and country to advance learning in the field. Relevant questions include:

- What worked better than expected?
- What has been more challenging than expected?
- What promising practices have been identified?
- Have expected savings been achieved or have costs been reduced in other areas?
- What can be done differently and better?
- How and at what intervals will the lessons be documented?
- Who should lessons be shared with?
- How can information be proactively standardized for better sharing and use over time?[43]

The effective implementation of R&E networking has the potential to offer significant improvements in learning, as well as accelerating the trajectory of innovation in education. Once districts have effectively implemented high-speed bandwidth, they should deeply consider what comes next. Fostering a culture of ongoing innovation is essential for assessing opportunities for future developments, including identifying new challenges that R&E networks can address and how those solutions can become institutionalized.

Recommendation 4: Actively Participate in the R&E Network Community

Among the numerous values of R&E networks are their vibrant and engaging communities. There are many ways to reap the benefits of engaging in the R&E networking community. Advanced connectivity is just the beginning. Participants can also access the vast network of people willing to share a wealth of expertise, experiences, and resources enabled by the advanced networking infrastructure. The Internet2 Muse site is designed to help users connect, discover, share, and create with others in the R&E networking community.

In R&E networks, end users can ultimately dictate the specifications and uses of the network and the services it offers to a degree unheard of in the commercial realm. This input ranges from technical needs such as bandwidth, latency, jitter, and packet loss to applications for teaching and learning. With the users being deeply involved in the service design and operational processes, R&E networks anticipate user requirements rather than react to the emerging demands of the users. There are many ways to engage with an R&E network provider and the R&E community. Here are just a few actions that can be taken with the help of the Internet2 K20 Muse database:[44]

- **Find Collaborators:** Search for people with similar interests or find organizations with common interests and collaborate.
- **Join an Interest Group:** This is where people can connect around a common interest or theme. Interest group participation is open to everyone, even people not connected to an R&E network. Users can determine if the R&E network activities meet specific teaching and learning interests. Interest groups can also have specific projects or events associated with them. If an interest group related to a specific topic does not exist, users are invited to create one and invite other community members to join.
- **Participate in a Project:** Projects are where people convene to leverage R&E networks in creative ways, such as organizing a series of HD videoconferencing programs between presidential libraries and K-12 schools. Or, perhaps teachers and students want to explore using the school's R&E network to connect with a remote-enabled undersea observatory. The possibilities are only bound by imagination.
- **Participate in Events:** Once connected to an R&E network, organize a webinar or a virtual team meeting as part of a particular project or interest group. Find and participate in an upcoming videoconferencing program or webcast. The R&E networking community thrives on making new connections, coming together around common interests, and celebrating those connections in projects and events that showcase the power of advanced networking.

Metcalfe's Law dictates that networks increase in value the more that they are interlinked;[45] the growth and evolution of R&E networks illustrates this law through its furthering of human and technical interlinking. Participating in the R&E networking community allows users to realize new opportunities for experimentation and development. The ability to access a network of people, projects, and activities across the formal and informal".edu" spectrum can lead to new ideas and enable current visions for education (such as gamification and virtual reality) to become part of an everyday school experience.

Conclusion

To foster innovation and adapt to global and societal needs, schools must be structured in ways that allow for flexibility and spur creativity and entrepreneurial thinking. In terms of broadband investment, this trend may enable educators and policymakers to take the long view and weigh not only the short-term expenses involved in adoption, but also the long-term benefit of deep integration and culture change. Technology infused innovations such as those facilitated by R&E networks are poised as a disruptive innovation with the potential to bring about systemic change.

As the transformational impact of high-speed, high-quality bandwidth continues to unfold, its ultimate effect will be greatly influenced by policy and culture. Decoupling learning innovation from norms such as class size, seat time, and instructional hours, and instead focusing on outcomes such as mastery will help school leaders advance deeper learning approaches. Providing adequate infrastructure along with supporting devices and bandwidth will make learning innovation possible. Accountability measures in education will need to reflect the reality that innovations improve over time, and that cost savings, improved outcomes, and efficiency will eventually be realized.[46]

With technology now at the center of many daily educational activities, school leaders can use the advanced connectivity offered by R&E networks to deliver reliable, quality service that will ensure that learners do not get distracted by the abundance of information and technology, and encourage mindful use of technology so that students stay aware of their digital footprint. As education aligns closer with technological trends, teachers will have a greater role in promoting the interconnectedness between technology, learning, and bandwidth, encouraging students to engage in experiences that are crucial to developing academic and contextual competencies.

As the panel of experts underscored, for educators and their students, the most valuable skillset is one that includes seamless technology integration in teaching and learning processes. This integration empowers educators to replace barriers created by poor connectivity with transformative opportunities enabled by ultra-high-speed, reliable connections. The goal is that students will ultimately define and attain the best uses of technology in lifelong learning and workplace activities.

The panel of experts expressed enthusiasm and interest in evolving education with a keen focus on first institutionalizing, making routine, and scaling current developments stemming from online learning, including BYOD and learning personalization. This process of perfecting widespread implementation of the learning and teaching possibilities at hand will set the scene for revolutionary educational transformation.

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End Notes

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