K-20 INFORMATION TECHNOLOGY:

How to Maintain an Intelligent Infrastructure

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Preface

Like all of our eBooks and eReports, this document is a synsthesis of desparate and complex topics into easy-to-understand words. It is meant to save the reader time by condensing down what is often complex and overly technical education technology language into a much more digestible and easy-to-follow format.

Introduction

The adjective "smart" does not come with one hard and clear definition. It has different meanings to different people. When applied to "information technology infrastructure" we can easily find ourselves traversing across a broad landscape dotted with numerous important points of concern, key issues and trends, all of which can be considered "smart." When segmented into K-12, community colleges, and 4-year undergraduate and graduate-level colleges and universities, the highest points of concern are both similar and vastly different. Content filtering strategies, for instance, are more of an issue in the K-12 arena than in higher education. The management of BYOD is vastly different in higher education than it is in K-12. Wi-Fi challenges, strategies and implementations are not the same across education sectors. IT-related human resource management and professional development are totally different in higher education than in K-12. New developments in the network software arena, such as software defined networking (SDN) and Open Flow standards are typically unrecognizable in K-12 but garnering big news and excitement at research universities. Overall, the list of concerns, key issues and trends continues to demand the close attention of IT professionals and K-20 faculty, staff and administrators on numerous levels.

The one common denominator in education at all levels, however, is the simple truth that we live in a digital age that brings hard-to-keep-up-with, unprecedented, and alarmingly fast changes to K-20 from both pedagogical and business perspectives. Staying on top of what specifically needs to be accomplished now and well into the future for sustaining an adequate and appropriate infrastructure is where the word "smart" comes into play. In other words, all educators should at the very least know what the broad landscape and most important points of concern look like, as well as have a solid notion of what next steps need to be taken and when to take them. That is what this report is about.

The full spectrum of a K-20 IT infrastructure ranges from managing telecommunication and Internet services to networking systems, security, storage, software adoption, data center consolidation and virtualization, understanding the cloud, staying abreast of the latest in professional development offerings and human resources development, and much more. However, it is not so much about what comprises the smart infrastructure of today and tomorrow but rather what directions, trends and strategies educators need to pay closest attention to in order to be considered modern and remain relevant and sustainable in today's changing digital age.

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How the Proliferation of Wireless Devices and Demand for Increased Broadband has Brought New Challenges

The very basic and prime underlying foundation of any smart infrastructure entails providing smooth, fast and uninterrupted access to anyone who has the privilege of traveling through a network and onto the Internet. This basic privilege, however, presents its own set of challenges primarily because of the growing proliferation of bandwidth-eating, wireless-enabled devices that students, faculty and administrators now carry with them and utilize when they arrive on a campus and enter buildings. Plus, the growing adoption of wireless devices in the classroom continues to show that from a pedagogical perspective, such devices can indeed bring about positive and engaging teaching and learning experiences at all levels of education, K through 20. So, adequately supporting this proliferation is imperative, but it is also fraught with maintenance, process and activity challenges that can be both costly and difficult to enable.

This is really no surprise when you consider what many of the most current studies tell us about the proliferation of wireless devices in educational settings.

Most college and university students (86%) own laptops as their primary computer device for academic purposes, but more students in 2012 than in previous years owned tablets (15%), smartphones (62%), and/or e-readers (12%). A little more than 30% of college and university students also utilize desktops for academic purposes. However, from 2004 through 2012, there has been a distinct decline in desktop computer and cellular phone usage, with laptops, tablets and smartphone usage replacing desktops and cell phones for academic purposes. Overall, students utilize both the MAC and Windows platforms, with about 86% of higher education institutions offering full help-desk support for Windows and 78% offering full help-desk support for Mac. [1]

> Nearly all students reported that basic institutional services and resources are available online or via mobile device applications and the majority of students who have a handheld mobile device have used it to access a service or resource. Institutional service offerings are most widespread for grade checking (85%), course websites/online syllabi (83%) and course/learning management systems (83%). [2]

In K-12, mobile devises and apps along with tablet computing are two leading technologies that are likely to enter the mainstream for teaching, learning and creative inquiry in the next 12 months. It's quite obvious across the country that schools are moving in this direction. Mobile devices are no longer being banned in K-12, with schools rethinking their policies and starting to implement a bring-your-own-device (BYOD), a one-to-one strategy, or a hybrid of both strategies. [3]

> The potential applications of mobiles are vast and range from graphing complex mathematical equations to storing and sharing notes and e-book annotations. Apps in particular are the fastest growing dimension of the mobile space in the K-12 sector right now, with impacts on virtually every aspect of informal life, and increasingly, potential in almost every academic discipline. [4]

"Higher education institutions are now designing apps tailored to educational and research needs across the curriculum." In addition, specifically with regard to tablet usage:

> People tend to use tablets to supplement and not replace smartphones. They are viewed as less disruptive tools (no phone ringing and no incoming text messages) which make them ideal tools for learning opportunities. Because tablets are able to tap into all the advantages that mobile apps bring to smaller devices, but in a large format, higher education institutions are seeing them not just as an affordable solution for one-to-one learning, but also as a feature-rich tool for field and lab work, often times replacing far more expensive and cumbersome devices and equipment. [5]

A Center for Digital Education (CDE) survey with responses from 142 IT professionals in K-20 revealed that 85% of faculty and staff bring a personal device to work with them (laptop, tablet or smartphone) that they use to access their school or college's network. In addition, 76% of students do the same.

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Supporting Increased Device Usage with a Strong Wi-Fi Infrastructure

All this does not necessarily mean that everyone has clear, fast and uninterrupted broadband connections all the time, regardless of what device or app they happen to be utilizing at any given moment. In order for such consistent smooth sailing to occur, institutions must maintain an up-to-date and sophisticated Wi-Fi infrastructure plan that can grow along with the inevitability of continuously increasing bandwidth usage across their networks.

In some cases, IT departments try to avoid more investment in relatively expensive network and bandwidth upgrades by incorporating tools that examine and measure user bandwidth consumption across the campus or school. These tools provide the ability to subsequently segment and/or prioritize certain types of traffic. For example, a "power-user" at a college or university is often a residential student who arrives to his dorm room with a smart phone, laptop, and tablet that connect to the institution's wireless network along with a gaming counsel that he plugs into his room's Ethernet port. This power user not only eats up extraordinary amounts of bandwidth playing games online, but he consistently streams rich media content over his Wi-Fi- enabled devices, such as YouTube videos and Netflix movies, on a regular basis. While the power user consumes the pipeline, his roommate, who may be a relatively passive user and happens to be on the same shared network passing through the same access point, is having trouble doing a simple web-based search or getting logged into his Blackboard account for an essay he has to compose for tomorrow's English 101 assignment deadline.

With the right tools, the power user can be monitored and segmented into a user-type category that puts limits on his broadband consumption and/or reroutes him onto an area of the network that would not interfere with the other passive user, thus making everyone's online experience pleasant and uninterrupted. The institution can also charge the power-using student an additional technology fee for increased connectivity permissions.

These types of services fall under the banner of "traffic management" that integrate with different types of authentications and indentify user names and roles (teacher or student or researcher, for instance) and then surgically provision bandwidth, controlling and managing the content that is most appropriate for any particular user. [6]

In another scenario, an innovative high school teacher may adopt the use of technology in the classroom by distributing school-purchased, classroom-only-based iPads to all of her students in her freshman biology class. The content these students access during class on their iPads includes high-definition videos and sophisticated electronic simulations that take up a lot of bandwidth. With traffic management tools, the high school teacher in this scenario is able to dynamically deliver videos at a relatively higher tier of bandwidth than what's available to other classrooms throughout the building that are not in need of such connectivity. The teacher also has the capability to ensure that these students get access to only those online materials that she deems relevant to her instructional methods, so the students do not have unfettered access to whatever they may want.

Another traffic management strategy entails installing "high-gain" antennas that can maximize an existing or new router's signal strength. Ruckus Wireless, for instance, is a key player in the advancement of state-of-the-art smart antenna and radio frequency (RF) traffic engineering technologies. Ruckus has developed Wi-Fi antenna-oriented systems that maneuver RF signals around possible interference and eliminate Wi-Fi dead spots while increasing the range and performance of Wi-Fi networks. In short, these antenna-oriented systems automatically enable Wi-Fi that reaches farther and is inherently more reliable. [7]

Routers with high-gain antennas and embedded software allow for multiple devices to operate effectively beneath one access point. For example, an access point that may have on average of three devices per user would not pose a problem if the appropriate antenna technology was installed. [8]

Regardless of all the traffic management services now available to IT professionals for enhancing Wi-Fi networks, the most frequently utilized option for enhancing Wi-Fi at any institution is to physically deploy more access points, which brings both new device costs and new labor costs. Adding access points entails installing them in ceilings and under stairwells, for example – basically in places on a campus where people work, study and/or live. Installation of new access points usually occurs during vacation periods or in between semesters when the campus is not so heavily populated. However, "there is never really a good time to do this, because you typically don't know how well everything winds up working until students actually show up on campus," says Lev Gonick, former Vice President, Information Technology Services and CIO Case Western Reserve University. "The tools that are available for monitoring Wi-Fi are significantly better than what they were back in the late 90s, when we first started to deploy Wi-Fi, but they are still not as robust as we'd like them to be," Gonick adds. For one, "Wi-Fi is and always will be a shared network resource – that is to say if there are 10 people on the highway consuming the road they will have a very different experience than if there were 100 people on the highway. It's a fundamental design constraint that we have to live with." [9]

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The Nature of Building Reliable Wi-Fi

In general, K-12 schools are not as equipped as they need to be in their development and support of reliable Wireless Local Area Networks (WLANs) when compared to higher education, but all education sectors today have their fair share of challenges, and all must have strong strategic plans in place that focus on total integration of wireless and mobile technologies to meet the growing usage of online-based instructional and assessment-oriented (both summative and formative) resources and tools that are readily available and proven to be highly useful for getting today's so-called "digital-native" student population more engaged in learning. Plus, many institutions, in K-12 or in higher education, frequently have to deal with old building designs that have multiple enclosed classrooms, long hallways, and remote and temporary buildings. Or, in many cases the older buildings on campus have been built with construction materials that frequently prevent radio frequencies from smoothly passing through walls.

> Traditional WLAN solutions require complex site surveys, channel planning and ongoing radio frequency tuning. To complicate matters, WLAN deployments are typically phased in over time, necessitating ongoing changes to the network design. The wireless deployment may also be modified as more users are added, or new applications are deployed. These changes to the WLAN design are extremely complicated to plan, with potential ripple effects on the existing deployment, due to the limited number of non-overlapping (usable) channels. In particularly crowded areas, moreover, access points (APs) are placed closer together to take advantage of higher data rates, increasing the speed at which clients transmit data. However, careful planning to avoid adjacent APs having the same channel only increases channel interference and network congestion.[10]

From a basic level of understanding, below are some recommendations for educators to take under consideration when charting a course of action for developing effective WLANs for teaching, learning and operations:

1. Basic connectivity for conducting simple research for term papers, communicating by email, updating announcements – meaning relatively low-bandwidth activities requires a minimum of 10 Kbps student/staff broadband connection; utilizing online educational tools and resources such as accessing more dynamic content over the Internet with a laptop or mobile device, collaborating with peers, downloading videos, and receiving and posting assignments on the school's learning management system requires a minimum of a 50 Kbps student/staff broadband connection; exploiting a fuller potential of connectivity to include accessing rich, multimedia-enhanced content, accessing e-textbooks, regularly downloading streaming media, going on virtual field trips, and conducting uninterrupted online formative and summative assessments requires a minimum of 100 Kbps student/staff broadband connection.

2. Internal wide area network connections from the district to each school and among schools within the district should be at least 1 Gbps per 1,000 students/staff by 2014-15 and at least 10 Gbps per 1,000 students/staff by 2017-18. [11]

3. Smart WLAN architecture addresses the aforementioned requirements and applications as well as user behavior by combining centralized security and management with system wide air traffic coordination and control. [12]

4. When committing to the deployment of advanced wireless technology, network administrators must ensure that every piece of the WLAN is both reliable and compatible with the other pieces of the network. The best way to ensure compatibility is to find an equipment provider offering a broad range of wired and wireless networking gear.[13]

Regarding connectivity needs and stature, a CDE survey showed that only 32% said that their connectivity was good enough for learning applications and downloading of digital content. Only 29% said their connectivity was adequate for online testing and assessment, and 30% said their connectivity meets their needs for video streaming. The reasons listed for connectivity deficiencies ranged from 11% claiming their connections were too slow, 12% saying they lacked wireless coverage, and 21% admitting that they had to deal with an overall lack of capacity to adequately serve students and staff.

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A Word About Federal Funding

E-Rate is the federally funded initiative that provides grants to K-12 for bandwidth upgrades. Eligible schools can obtain discounts up to 90% to help obtain affordable telecommunications and Internet access. More than $59 million in E-Rate funding came through between 1998 and 2010. The discounts are based on the number of eligible students under the National School Lunch Program, with schools in low-income areas qualifying for higher discounts.

E-Rate does not cover network management costs. E-Rate priorities include the cost of Internet access through the wide variety of service providers available and hardware and software costs that sit in a school or library for the purpose of education usage, such as routers and wireless access points, cable, telephone systems and data servers for the purpose of communication. Basically anything that has to do with communication devices at a school or library is covered under E-Rate. Network management services, however, are not covered, as well as the cost of actual devices. E-Rate, for example, will cover the server and the cabling for a phone and/or computing system, but it will not cover the actual cost of the actual phone or the computer. For more information about E-Rate, visit the administrative arm of this initiative at the Universal Service Administrative Company (USAC) website . [14]

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BYOD or One-to-One?

Once a school district has indeed come to the conclusion that deploying a smart WLAN is imperative and begins to move forward down a progressive pathway, the question of whether or not to support a BYOD or one-to-one strategy – or both – becomes a high priority. Unlike in higher education, where supporting BYOD is a must-have strategy if only to remain competitive in the marketplace (students will leave if they don't have great access via any device 24/7), and where such things as content filtering and controlling access and devices are not mandatory, K-12 administrators must come to grips with such things as equity, security, and student identity and privacy issues that present challenges that have a huge impact on costs.

Additionally, K-12 is being forced to deal with readiness issues that fall under the banner of high stakes online testing in preparation for the Common Core State Standards (CCSS) that go into effect in 2014 (see section on CCSS below). Decisions related to a BYOD or a one-to-one strategy play an important role concerning CCSS online testing issues. Many IT professionals agree that one-to-one is ultimately the wisest, easiest-to-manage and operate way to go. For now, however, many schools across the country are implementing less-expensive BYOD strategies (because they don't have to purchase devices as students bring their own) as a kind of testing ground to see how everything works with an eye toward a future in which they will be able to implement a full-scale one-to-one program.

A lot of schools across the country are piloting hybrid BYOD and one-to-one programs, with educators asking questions concerning what are the most appropriate devices, what are the expectations overall, what kind of professional development may be required, and what kind of curriculum development will occur through the use of these devices. In addition, how schools marry these trials and pilots to ultimately work with the CCSS is a big question on everyone's minds. In short, schools are buying mobile handheld devices to figure out what they are actually going to do with them. Their plans are to come with a plan.

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Figuring Out the Total Learning Environment

The learning environment is changing to one in which students connect to the Internet or a private online network to do their homework outside of the classroom. Flipped classrooms, for instance, where class lectures, instructional –based videos and other content are viewed online at home and then discussed in the school, are growing in popularity. So, it has become obvious that the development of a smart infrastructure should start to include strategies for outside-of-the-classroom connectivity. Asking questions about what kind of bandwidth students have from home is becoming a requirement for figuring out the total learning environment. This is an area of concern that is far from being resolved, especially since 80% of k-12 schools themselves do not have adequate bandwidth. [15]

So, questions about access, questions about how online resources can be better utilized for teaching and learning, questions about how to find the right equipment to support an expanding learning environment are coming to the forefront. When it comes to BYOD, what is an adequate device? Is it a MacBook Pro with a retina display, an inexpensive smart phone, and iPad, an Android, etc.? If 30 students bring 30 different devices to school, who is responsible for making sure that these devices are consistently working properly? Who supports them? Consequently, standards and common denominators need to be defined. Going with one device, or several devices that all have the same capabilities and can all run the same applications, looks like the logical step in the right direction. [16]

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Common Core State Standards

At the start of the 2014-15 school year, the new CCSS goes into effect, including new online assessments in English and in math. Under the direction of 47 states that have signed on with the Partnership for Assessment of Readiness for College and Careers (PARCC – with 22 states participating) and the Smarter Balanced Assessment Consortium (SMARTER Balanced – with 25 states participating), these new online summative and formative assessments will require schools to change their instruction to align with CCSS as well as meet minimum technology and bandwidth specifications that have recently been announced. Educators see this as a new and exciting opportunity to transform K-12 education.

> Taken together, the implementation of CCSS, the shift to online assessments, the availability of affordable devices, and the growing number of high-quality digital instructional tools create an unprecedented opportunity to fundamentally shift the education system to personalize learning around the individual needs of every student… States and districts must act now. [17]

PARCCC and SMARTER Balanced are building similar approaches for this new generation of online assessment systems that measure CCSS, featuring a variety of item types as well as technology-enhanced and performance-based tasks, online reporting, and digital resource libraries. These online assessments will use computer scoring and expert graders with an estimated results turnaround of about two weeks. "In sum, online assessments will power the future of customized learning – the best chance we have to dramatically boost achievement levels and better prepare students for college and career." [18] SMARTER Balanced has a website with representative items and tests to date, as does PARCC. [19,20]

Some of the technological challenges that are expected to come with the adoption of this new generation of online summative and formative assessments include districts having to increase their current levels of network capacity in both wire line and wireless access. Bandwidth will have to be increased to accommodate relatively large numbers of students taking these tests at the same time, with some educators saying that a T1 connection should be sufficient for a simultaneous testing of 64 students and an installation of a local cache service to reduce bandwidth requirements to enable up to 1,500 simultaneous online test takers. A recent Center for Digital Education (CDE) survey of 152 responding education technology professionals showed 75% noting that their district's adoption plan was either in the works on in an early stage, with completion no later than spring of 2014. [21] For many school districts, meeting all the challenges that are coming down due to CCSS will require the deployment of new partnerships with leading technology vendors in the field.

> In the face of shrinking budgets and skyrocketing costs for technology, partnering with vendors and/or solution providers could save districts big bucks by reducing overhead. This relationship can be limited to specific functions (such as accounts payable) or it can be as broad-sweeping as total outsourced network management. ISPs and solution providers can become trusted confidants, skilled sounding boards for technology ideas that might need a little extra expert opinion along the way. What's more, ongoing maintenance and monitoring contracts are becoming increasingly popular, for districts with LANs and WANs, allowing third parties to come in and support these arrangements as a good strategy to jumpstart growth without hiring any new employees. [22]

On the other hand, some educators believe that figuring out how a district can deploy the right network and bandwidth for online tests is not what's most disruptive when it comes to CCSS.

> The network that you will need for testing is a fraction of the network because it is all questions and answers with a limited number of interactions. The network handling email, video streams and everything else you need to teach is a much bigger network than what you need to administer an online test. That is where the haves and have-nots will exist. You will have schools with limited resources, schools that cannot give a student a device all of the time or do not have the network capacity and cannot afford the latest and greatest software services. Those are the schools that will be at a disadvantage, especially when they are compared to schools where many of their students already own and use anywhere from one to three devices.[23]

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The New World of Software Defined Networking (SDN)

While higher education does share many of the same challenges as K-12 when it comes to supporting high efficiency WLANs, or the effective construction of high technology smart infrastructure, in general, the two education sectors do have some distinct differences concerning how they are able to deal with important infrastructure maintenance and improvement issues. For one, K-12 schools, in particular, usually don't have the high level of experienced IT staff capable of deploying and managing some of the relatively new-on-the-scene IT technologies that are starting to play out in higher education. A large percentage of K-12 IT directors – some say in the range of 80 percent – are under qualified.

Additionally, school districts typically have relatively small IT staffs, where the leading IT person has to be a jack-of-all-trades, so to speak. The same IT staff member who handles network issues may also have to handle security issues. In higher education, on the other hand, especially at research universities, there's an expert on networking and an expert on security. [24]

An area of new and exciting IT technological concerns in which higher education IT professionals, particularly at research universities, are paying closer attention to is in areas referred to as "Software Defined Networking" (SDN) and "Open Flow" standards. While not entirely brand new, the latest developments in SDN and Open Flow could bring unprecedented efficiencies of scale and cost savings relative to network management.

What is SDN and what is Open Flow? SDN "enables direct programmatic control of the network, coupled with end-user-driven applications and needs, enabling operators to efficiently use their network and operational resources." [25] Open Flow is an "open standard that enables researchers to run experimental protocol in campus networks. [It] provides standard hook for researchers to run experiments without exposing internal working of vendor devises." [26]

Gonick provides an easy-to-digest definition:

> SDN is an emerging standard for virtualizing the network. In the SDN world you can actually take, if you will, channels, or slices, and dynamically provision a network experience from end to end, not for the entire network, but let's say just for two labs that need to connect to each other, with the ability to characterize the network experience either by bandwidth or more likely by the protocols that can run over that bandwidth in ways that do not disrupt the experiences of others on the network. It basically allows for the creation of channels for different ways of consuming network resources. [27]

At Clemson University, an SDN team has been created under the leadership of Daniel Schmiedt, executive director of network services and telecommunications, in collaboration with Clemson's School of Computing, along with support from a National Science Foundation (NSF) grant. This team has already implemented a data analysis network through SDN/Open Flow technologies and is currently working on broadly improving network performance across campus in 20 buildings to connect with part of Clemson's high performance computing cluster at 100 Gigabyte connectivity.

"Most outside entities are so used to thinking of networking as plumbing that you move data through, and to really get heads around what is possible with a truly programmable network is hard to accomplish," says Schmiedt. "We are used to operating in a paradigm where you literally take data and pour it into a big network, and you expect the network to forward the data and move it out into the right place. But we are shifting into a world where certainly if you want to make SDN do that, it will, and I think the possibilities for true innovation exist outside of that paradigm." [28]

CISCO and Brocade are two companies showing a commitment to support and develop standards around Open Flow and SDN. According to Schmiedt, in addition to partnering with a vendor that has a roadmap going in this direction, IT leaders at universities need to collaborate with faculty and staff from their computer science and computer engineering departments. "You need to build a relationship with your academic side," he says. "Because you are sitting on a powder keg of possibilities if you can get collaboration between your professional networking staff and the academic part of your university." [29]

Those who want to learn more about SDN and Open Flow can take advantage of Internet 2's "SDN Collaboration Space," a workgroup that is collecting feedback from the university community (includes Stanford, Clemson, Georgia Tech, Princeton, Rutgers, the University of Wisconsin and the University of Washington) that has taken a keen interest on the innovative use of SDN by fostering relationships between academic and IT personnel. [30]

Another great resource for SDN can be found at the Open Networking Foundation (ONF), which categorized SDN and Open Flow in a paper titled "The New Norm for Networks."

> Software Defined Networking provides a new, dynamic network architecture that transforms traditional network backbones into rich service delivery platforms. By decoupling the network control and data planes, Open Flow-based SDN architecture abstracts the underlying infrastructure from the applications that use it, allowing the network to become as programmable and manageable at scale as the computer infrastructure that it increasingly resembles. An SDN approach fosters network virtualization, enabling IT staff to manage their servers, applications, storage, and networks with a common approach and tool set. Whether in a carrier environment or enterprise data center and campus, SDN adoption can improve network manageability, scalability, and agility. [31]

SDN is an example of how the right programmable and open software can help bring down costs and solve some of education's greatest IT challenges. The development of such sophisticated open software is a trend that has great potential on many levels. Software development basically improves hardware; it learns behaviors, optimizes services, and helps to improve our lives. [32]

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Virtualization

Software development has brought about meaningful advances in the area of virtualization as well as in the field of data analysis and assessment, or what is often referred to as "Big Data" (see section below). In the area of virtualization technologies, IT professionals today are coming to grips with virtualizing networks, servers, desktops and data centers to reduce their operating expenses.
Old and or underutilized desktop computers waiting to be replaced, for instance, are being transformed into reliable workstations connected to the Internet or a private network that gives students and faculty access to the applications and resources they need. In other words, access can be provided regardless of the age of a computer or laptop through the utilization of desktop virtualization. In addition, the newer tablets and other mobile devices can be virtualized for e-learning, enabling broader student access to applications and resources. This also gives IT departments the ability to centralize applications and consequently lessen the need for what can be expensive software licensing (such as for analytics, biotech and other sophisticated modeling tools). [33]

On a much larger scale of virtualization technologies, the virtualization of data centers reveals some promising efficiencies of scale, noted as being able to provide savings on floor space, power and cooling costs, as well as on the possibility of more efficient, more centralized control and enhancements to servers, storage challenges, and network management.

> Server virtualization by itself cannot yield all the benefits of virtualization. Virtualizing the data center is a holistic approach to server, storage, network processes and management to create a dynamic, efficient and agile infrastructure. A virtual data center leverages technologies that abstract the relationship between the services offered and the physical hardware. This provides the obvious benefit of consolidating resources into pools that make sharing more efficient. The power of this move multiplies as integration with compute, storage, network, management and security technologies are leveraged to create a synergistic approach. [34]

In the end, however, managing many of the complexities that are part and parcel of any type of virtualization deployment requires strong planning as, in general, solutions and promised capabilities tend to vary tremendously between vendors. In short, due diligence is mandatory before taking on any kind of virtualization implementation.

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The concept of analyzing large amounts of data with sophisticated, newly developed software that will in turn result in more efficient and meaningful educational practices in K-20 can be considered a relatively early effort that has the potential to transform education in ways never before seen. This is software development at a new level of superiority as it portends to make the effective personalization of education a new reality. It also portends to transform administrative software, such as the creation of better student information, registration and advisement systems, a new reality.

When education moved from an analog world to a digital world, an opportunity was created that gave educators the ability to track every piece of information that passes through a course of study or institutional infrastructure. How much time, where was it located, how often was it accessed, what were the performance standards? if this kind of information is already known through data analysis, then everyone going down the same track is no longer necessary. We can send individual students off to a different track that is more enriching or fulfills some of the gaps in their knowledge. In this scenario, learning can become more just-in-time. We can know at any moment in time what a student knows, what they don't know, and what their next steps should be to get to where they need to be. That is what Big Data can accomplish.

Effective data requires sound metrics. Systems basically have to be able take information, process it, apply it, and direct it to the right people at the right time in order to make the right decisions. The idea then becomes one related to automation, where, for example, a student in an online or blended course who takes a test on Tuesday will know the results of that test, and much more, on Wednesday. So, when that student logs on again, the system lets them know that these are the things they did not understand. Based on that, here is today's curriculum that they should be looking at. Also, please produce this particular performance standard at the end of the day so the teacher will know that you have done what you needed to do.

In short, effective data analysis and online assessment gives the teacher more ways to intervene. This, in turn, helps to lessen all that organizational, processing, and observational time that teachers put in, allowing the teacher to do more of what they really want to do, which is teach and see the results of their teaching. It can help teachers and students more effectively work through a difficult concept, or make something more meaningful, or lead to a discussion around a topic and how it can be applied to today's world.

A smart data analysis and assessment infrastructure takes the administrative tedium out of the instructional process. In essence, the class becomes more efficient. It also becomes more fun to students because now they are doing things that are more personalized than if they have to sit through a class that was designed for a group of 30 students.

For more information on how data is being applied in educational settings, mostly in higher education, see the Predictive Analytics Reporting (PAR) Framework "a multi-institutional data mining project that brings together 2 year, 4 year, public, proprietary, traditional, and progressive institutions to collaborate on identifying points of student loss and to find effective practices that improve student retention in U.S. higher education."[35] Another organization that has a strong focus on using data analysis and assessment as they relate to student retention and learning is the National Institute for Learning Outcomes Assessment (NILOA), whose "primary objective is to discover and disseminate ways that academic programs and institutions can productively use assessment data internally to inform and strengthen undergraduate education, and externally to communicate with policy makers, families and other stakeholders." [36]

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The Cloud and SaaS?

It is necessary to at least briefly address the implications of cloud computing as it relates to constructing a smart infrastructure in K-20 education. Wikipedia defines cloud computing as "the use of computing resources (hardware and software) that are delivered as a service over a network (typically the Internet). The name comes from the use of a cloud-shaped symbol as an abstraction for the complex infrastructure it contains in system diagrams. Cloud computing entrusts remote services with a user's data, software and computation." [37] Basically users of a cloud service have access to a virtual space that provides a wide variety of online services and applications that can be accessed from any Internet-enabled device. A cloud can be a private cloud only accessible via pre-authorized authentication, or it can be a public cloud accessible by anyone. The users of cloud services consume online applications through what's referred to as a Software-as-a-Service (SaaS) model.

In particular, the SaaS marketplace is growing fast, reaching $21.2 billion and projected to grow to $132.5 billion by 2020, as noted by Forrester Research Inc in 2011. With SaaS, institutions can save on upfront costs that come with new deployments by not having to purchase and run applications that are available in the cloud. [38] Google's Gmail as well as Microfsoft's Hotmail are good examples of this kind of endeavor, as many schools have deployed free Gmail or Hotmail accounts for their students as opposed to paying for an email service provider. In addition, both Google and Microsoft Google and Microsoft have created their own suite of software applications, provided for free to educational institutions.

> By 2010, more than 8 million higher education students in the U.S. were using Google Apps. Similarly, Microsoft created Live@edu, which is a suite of free Microsoft services and applications including Hotmail. In early 2009, there were more than 3.5 million Live@edu higher education students. Just two years later, that number more than quadrupled to more than 15 million. [39]

Stay tuned as adoption of cloud-based technologies continues to grow at institutions across the country.

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Security

Concerns related to proper security is another vitally important concern in K-20, and security concerns are especially important when talking about cloud computing. As noted in a recent McKinsey & Company report:

> As attractive as cloud environments can be, they also come with new types of risks. Executives are asking whether external providers can protect sensitive data and also ensure compliance with regulations about where certain data can be stored and who can access the data. CIOs and CROs are also asking whether building private clouds creates a single point of vulnerability by aggregating many different types of sensitive data onto a single platform.[40]

Another challenge related to cloud adoption, or any kind of IT-related deployment on any level for that matter, and security issues, is whether or not the product and/or service conforms to education-based regulations and industry standards. IT professionals must do their homework and ensure that the utilization of any IT based product or service does not have a likelihood of enabling privacy breaches or data loss. This falls under the area of risk-management. Especially when it comes to the cloud, "it is still the early days of cloud computing, and risk-management decisions are highly dependent on the specifics of the situation." [41]

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The Further Development of Teaching and Learning in Blended and Fully Online Modalities

It's no secret that fully online and blended (hybrid face-to-face and online) learning environments have grown tremendously in recent years. The latest 2012 annual survey of online learning conducted by the Babson Survey Research Group, with support from the Sloan Consortium and Pearson, shows that more than 6.7 million higher education students took at least one online course during the fall 2011 term, an increase of 570,000 students over previous years. Thirty-two percent of higher education students take at least one course online, and 77 percent of academic leaders rate the learning outcomes in online education as the same or superior to face-to-face courses.[42]

Continuously developing a smart infrastructure that supports online learning and teaching is imperative across K-20. For instance, since the Obama administration took office in 2008, our nation's two-year institutions have gained more prominence on the national scene as the key catalysts to fulfill a college completion agenda that will put America back into the top rankings worldwide for number of college educated citizens. In order to meet this mission head on, community colleges have been developing more flexible fully online and hybrid education curriculums that help to enable busy working adults to upgrade their job skills as well as become more employable through, at minimum, workforce-targeted online certificate programs. Supporting innovative technology-driven efforts to increase college completion and help meet the needs of students at community colleges on multiple levels are the Lumina Foundation, [43] and the Bill & Melinda Gates Postsecondary Success Strategy.[44] Also, community college organizations, such as the League for Innovation in Community Colleges,[45] the American Association of Community Colleges,[46] and the Instructional Technology Council, [47] provide numerous resources for community colleges to further develop online education.

Rio Salado College, the largest public, non-profit, online two-year college – based in Tempe. Arizona with more than 41,000 online students – is a leading model for expanding access and providing the necessary student services for online learners. [48] The University of Maryland University College, the largest public, non-profit four-year and above institution - based in Adelphi, Maryland, serving more than 92,000 students at more than 150 locations worldwide and online - is also a leading model in the online teaching and learning arena, going back to the early 1990s. [49]

The Sloan Consortium [50] on the East Coast and WCET [51] out West are two higher education organizations that invest an enormous effort in supporting higher education's movement toward providing strong and effective online learning environments.

In K-12, the International Association for K-12 Online Learning (iNACOL) is the leading advocate for supporting activities and policies that remove barriers and support effective online education. [52]

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Beware of the "Black Hole"

In conclusion, we start with Casey Green, creator of the popular Campus Computing Project, who asks: "Has the campus investments in IT been effective for administration and operation and data and analytics? Investments are essential, but they have not been very effective. We have this ongoing conversation about how IT is viewed as a black hole because there is always a request for more, there is always something new. Yet, what we have does not always deliver on either promises or expectations or aspirations." [53]

So, it is important to realize that developing any kind of smart infrastructure requires IT professionals to understand what the market really offers and be fully aware of all the resources that are available to them in order to make informed decisions and ultimately create meaningful plans that can be incorporated in a manner that does not break the bank and can be implemented incrementally over time.
On another level, here's a statement worth pondering that was provided by Laura Patterson, CIO and associate VP, University of Michigan, that seems to encapsulate the whole issue of smart infrastructure:

> It's a very challenging time to be in IT. Smart infrastructure is the key, and the services are coming from everywhere. Providers are everywhere. The infrastructure that enables your users to get to the services they want but that also protects their security and enables them to be mobile and enables them to access information anywhere at any time from any device and do it in a way that is pure, is a challenge that everyone faces. But it's an exciting time; it's a great time. All of education is definitely in a period of disruptive change not unlike what the recording industry went through, what the movie industry went through, what the newspaper industry went through. We are in that type of disruptive change and it's very much written by technology, but also technology is the response.[54]

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