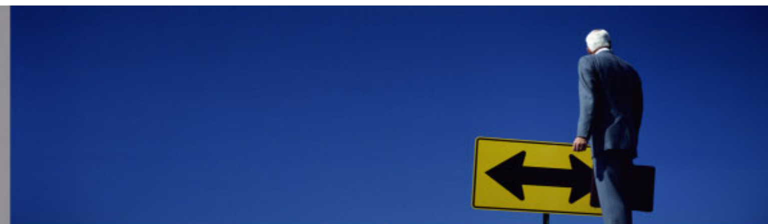
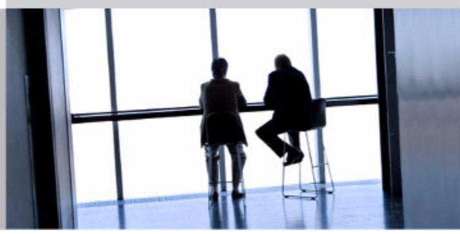
Education for a Smarter Planet: The Future of Learning

CIO Report on Enabling Technologies



Redguides
for Business Leaders



Dr. Jim Rudd
Christopher Davia
Patricia Sullivan

- Guidance to aid CIOs in strategic investment efforts
- The value of consumer IT, open platforms, and cloud computing in the future of education
- Practical examples of how enabling technologies are used today

Introduction

This IBM® Redguide™ publication is a supplement to the *Future of Learning: Executive Insights Report*. It provides an in-depth investigation into three enabling technologies and provides actionable guidance to aid CIO strategic and investment planning efforts. Specifically it discusses the value and role of consumer IT, open technologies, and cloud computing in the future of education. In addition, this guide provides real-world examples of the how these technologies work.

This guide includes the following topics:

- Executive overview
- Exploring the technologies that enable the educational continuum
- Consumer IT
- Open platforms
- Cloud computing
- Creating Education for a Smarter Planet
- A roadmap for enabling a future vision
- Other resources for more information

Executive overview

Over the next decade, educational institutions will face significant change, transforming their relationships with students, teachers, and the workers of tomorrow.

Signposts for the future are already visible, signaling significant changes to all segments of education as well as to their funders. These five signposts, which are technology immersion, personalized learning paths, knowledge skills, global integration, and economic alignment, are rapidly converging to produce a new and transformative paradigm that we call the *educational continuum*.

This continuum dissolves the traditional boundaries between academic levels, education providers, and economic development initiatives to provide a single system for life-long learning, skills development, and workforce training. To anticipate these challenges, educational and governmental leaders must urgently embark on a series of actions for transforming their educational institutions. CIOs will play a key role in this transformation.

Exploring the technologies that enable the educational continuum

As presented in the Executive Insights Report *Future of Learning: Enabling Economic Growth,* governments and educational institutions must anticipate the needs of their constituents. They must read the signposts of emerging trends and, in response, develop strategies, programs and services to prepare the next generation for this future society.

Signposts, which are indications of how events are likely to develop, provide insight for informing future programs and services. These signposts indicate transformational changes that will occur at traditional systems of education to support a continuum of education for the student of the future:

- Increasing technology literacy of students and technology integration into their everyday lives
- Evolving models for teaching and learning, allowing students to acquire skills that better prepare them for knowledge-based professions
- Improving interconnectivity of global resources which have eliminated traditional institutional boundaries allowing learning opportunities for new populations of youth and adult learners

Table 1 Signposts and their relationship to the educational continuum

Signpost for the future	Transformational strategy
Technology immersion	Any device learning
Personal learning paths	Student-centered processes
Knowledge skills	Learning communities
Global integration	Services specialization
Economic alignment	Systemic view of education

The following key technologies underlie these changes, holding the potential for helping to transform the student experience in the coming years:

- Consumer IT
- Open platforms
- Cloud technology

In aggregate, these technologies signal changes for student use of technology as well as teaching and learning methods, infrastructure models, and management strategies. How an educational institution implements and integrates these emerging technologies will be a key factor in whether it succeeds in the coming years. In this Redguide publication, we offer an in-depth investigation into these three enabling technologies to aid CIO strategic and investment planning efforts.

Consumer IT

Two consumer technologies will have a major influence over the evolution of education technology over the next several years. In this section, we discuss the roles of mobile technologies and social communities for the future of learning.

Mobile computing

Nearly a billion new mobile devices are manufactured worldwide every year,[1] and innovation in mobile communication continues at an unprecedented pace. The world has quickly embraced mobile phones and devices as the primary means for keeping in touch from afar. Mobile phones are becoming the world's most affordable and ubiquitous computing platform. By using hand-held devices, we can access the Internet from just about anywhere and provide content over broadband cellular networks and local wireless networks.

Although students today use their phones to post to their blogs, update their Facebook status, and add appointments to their online calendars, mobile-based campus applications have been slow to catch on due to several factors around security, infrastructure, and standardization.

We anticipate this state of affairs to change significantly in the next 3 to 7 years. In the future, mobile devices will transform education, allowing learning anytime, anywhere, and on any device. Why?

- The difference in computing power is dissolving between PCs and mobile devices. High-end mobile phones are already comparable in processing power to some low-end desktop PCs. In the future, the computing power of mobile devices will easily support memory-intensive applications that a few years ago were only possible on desktop PCs.
- Bandwidth continues to grow, which makes services and content easier to deliver at much higher performance levels.
- Device usability will continue to improve, with better form factors, higher screen resolution, and better economics, leading to even more widespread adoption. Amazon's Kindle and other eBooks have improved readability, allowing a transition from print-based materials and text books.
- Growing endorsement for software openness (Linux®, mobile Ajax, WebKit) by powerful market influencers, such as Google and Apple, are encouraging more innovations and rapid ecosystem growth among development and user communities.
- With greater bandwidth and processing power, there will be a significant opportunity for mobile multimedia as video becomes more important in the classroom.
- Presence information that can provide location and time information about where the user is, and what the user is doing, will play a significant role in the rapid development of location-based services for students, faculty, and staff. For example, location-based services will help students find their classmates, classrooms, and nearest ATMs, as well as help to ensure their physical security while walking across campus. As these location-based services evolve, it will be possible for the mobile network to recognize when a student moves from one environment to another environment, enabling all kinds of learning experiences that are not possible today.

[1] Communities Dominate Brands, "Putting 2.7 billion in context: Mobile phone users," 08 January 2007 http://www.communities-dominate.blogs.com/brands/2007/01/putting_27_bill.html

In today's mobile ecosystem, service providers and device providers are the gatekeepers for new user applications. This ecosystem will face profound disruption in the coming years (Figure 1). In the near future, after IP becomes widely available, Web-based services and IT service providers will gain much better access to the market and play a major role in determining the types of applications that will be offered to consumers and students.

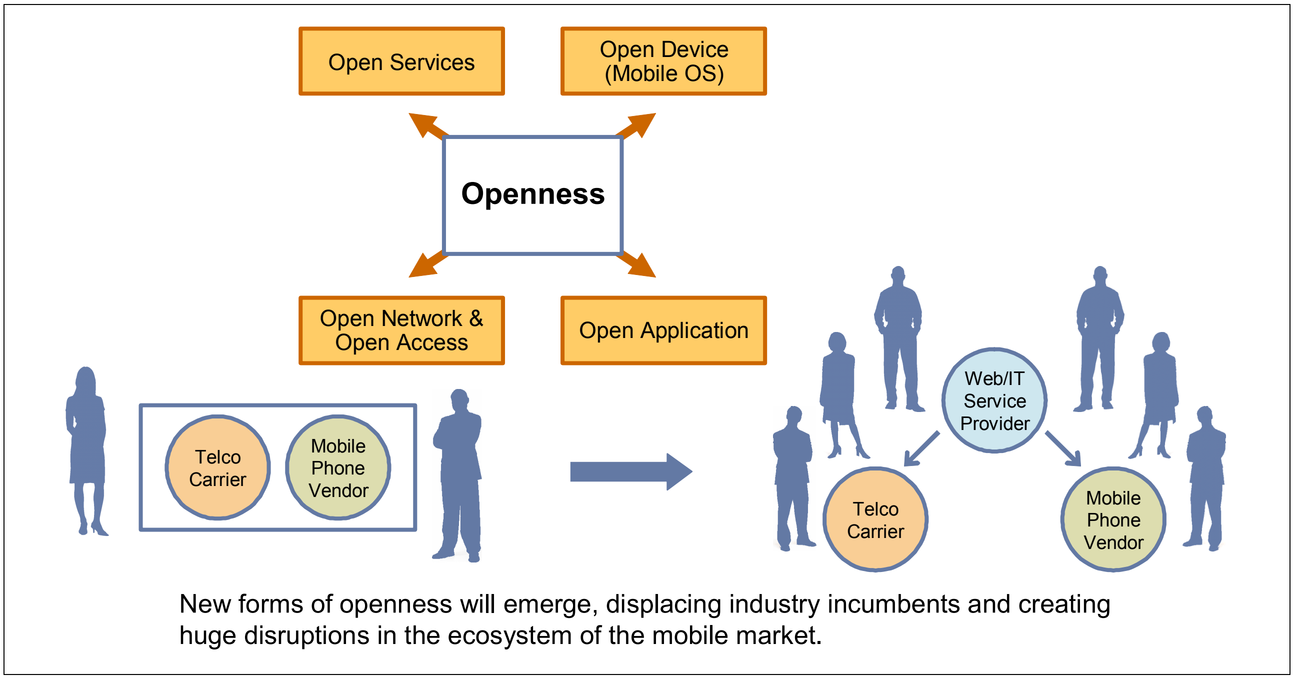


Figure 1 New forms of openness creating disruption in the mobile market's ecosystem

As a result, the traditionally regulated mobile market will face immense disorder as the open movement in network, device, application, and service aspects (for example, Google's Android initiative) will allow many more new players. This change will provide unique and potentially extraordinary value to learning institutions and their constituencies.

Today the mobile environment is generally not an IP environment. Data transmission rates are relatively slow. Typically, devices can transmit and receive at most one megabyte per second (Mbps) of data on most wireless handsets. However, low cost, high bandwidth wireless IP access is rapidly coming into the marketplace. For example, WiMax will approach 100 Mbps in the next 5 years, and in less than a decade, there will be more than one gigabyte per second (Gbps) of WiMax wireless access. Long Term Evolution of 3G (LTE3G) is expected to approach 100 Mbps of IP bandwidth by 2011. Other technologies will also be integrated to allow a continuum of IP transactions. For example, RFID allows us to get close to 1 Gbps in a near field, and WiFi will continue to drop in price.

When true IP wireless access exists, mobile devices will become the platforms for delivering most types of educational data, applications, and services. Today, this is something that is only possible through computers and fixed networks. Such applications as mobile video casts, mobile video file transfers, videoconferencing for classroom lectures, immersive interactive learning environments, and social networking applications will all be supported by mobile devices.

Openness in the mobile market

Another key mobile marketplace trend is the creation of more open and multiprovider services. In the mobile environment, typically the telephone carrier, service provider, and provider of the mobile device are the gatekeepers. In most cases, it is not possible to gain access to a new mobile application unless permission is obtained from both the service provider and, in many cases, the mobile device provider. As a result, innovation has historically been slow.

The open philosophy of the Web is slowly moving to mobile. For example, the infrastructure to the Mobile platform, that is the Internet service providers (ISP) and IT service providers, will become more open. Mobile openness is being driven by the following major forces:

- Consumers who want the freedom to download and use any software applications or services they choose
- Consumers who want the freedom to use their hand-held communications device with any wireless network they prefer
- Third parties that desire to provide wireless services (open services)
- Third parties (such as ISPs) that desire to interconnect at any technically feasible point (open networks)

Application development for the mobile platform

During the past several years, new programming technology has emerged to support widget-based Web applications stored on the mobile phone. This trend will continue with Web 2.0 related technologies (for example, Ajax and REST) to be adopted for the mobile platform.

With a smaller footprint and better performance, WebKit (Open Source Web Browser Engine) is becoming the runtime engine inside mobile phones to support these application widgets. WebKit is based on Web programming technologies, such as HTML, XML, and JavaScript™. Each vendor provides custom AJAX User Interface libraries and JavaScript access to local services. WebKit includes extensions for Advanced Graphics (OpenGL), Local Persistence (SQLite), and Media Extensions (audio and video).

These Web application widgets provide much richer user experiences and are friendlier to content from the Web. Because it shares the same Web programming model with Web applications, the barrier for educational Web developers to develop mobile applications will dissolve further.

Nokia, Google Android, and Apple iPhone are the major mobile application and platform vendors that are driving the adoption of this new model. Specifically they are adopting WebKit and promoting Web-based widget applications for mobile phones from a user interface and interaction aspect. In the following several years, we will see this new model become adopted by more mobile phone vendors and mobile software platform vendors, allowing a proliferation of application development across many industries, including education.

Mobile applications in education in the future

There will be a significant opportunity for the use of mobile multimedia to improve the overall learning experience as video becomes a more important element in the classroom. Mobile social networks will become a key element for delivering learning content in the form of targeted rich media that is specific to the individual. This can be foreseen in team-based higher learning as course work and group field study applications migrate to easy-to-use mobile devices.

Presence information about where the user is, what the user is doing, and the present state of the user will also play a significant role in improving the learning ecosystem between students, faculty, and staff. In the future, the mobile network will recognize when a student moves from one environment to another environment. That is, it might not be unusual to see a student watch a playback of their class on a cell phone or media tablet in the student union, for example. Then, later in their dorm room, the student might automatically transfer it to their TV or computer. We can imagine teachers carrying their class material on an RFID-enabled smart ID card. Upon entering the classroom, the teacher’s lesson plan is read off of the smart card and displayed automatically for students to review.

Social communities

A significant driver for teaching and learning in the future will be wider adoption of digital communities, driven mostly by mobility and globalization. The typical campus Web portal will further evolve into a “community platform,” where digital technologies such as social software, mobility, telepresence, and 3-D enablement will provide a portable and pervasive social platform for learning.

In terms of the classroom experience, there will be much less dependence on top-down institutionally delivered content and services. Instead, there will be a greater use of inexpensive personal social networking tools and channels to deliver content, both formal and informal.

Global corporations have spent the last several years making digital communities part of their strategy for connecting employees and constituents. These corporate experiences provide useful insight for education institutions who are also attempting to use social networking and online communities for teaching, learning, research, and administration.

Digital communities functional landscape

In the future, globally-based digital communities will enable transformation in educational pedagogy. They will introduce novel forms of real-time interaction and collaboration that will revolutionize traditional student-teacher relationships, roles, and responsibilities. To give perspective to the concept of digital communities, let us step back and look at how the typical campus community evolved. For hundreds of years, a learning community was characterized by geographic co-location of the buildings. This provided the following well-known advantages:

- Physical co-location-based collaboration makes it easy for collective one-to-one innovation and resource sharing.
- Creation of a sense of belonging was important to the social well-being of the university community.

In 2009, most institutions’ digital communities are characterized by one-to-many interactions of individuals with others, over the Web, mostly through e-mail and student mobile devices. But these interactions are hindered by today’s tools and technologies because communication (both synchronous and asynchronous) is neither easy nor seamless. As a result, physical co-location-based collaboration is still preferred.

To give perspective to the concept of digital communities, let us step back and look at how the typical campus community evolved. Figure 2 illustrates this evolution. For hundreds of years, a learning community was characterized by geographic co-location of the buildings.

- Historically, physical campuses provide two types of well-known advantages: a collaboration, knowledge and resource sharing sense of belonging, and social ties.
- However, an exploding number of global digital communities are emerging that leverage the Web.
- The tools for collaboration and interaction also continue to develop further attenuating the importance of physical co-location.

Figure 2 The evolution of social community

In the future, ease of collaboration will be the defining characteristic in the evolution of campus digital communities. These digital communities will continue to break the tie to geography and time, eventually creating new ways of socializing, collaborating, and working together. From today's e-mail and simple social networks, such as Facebook, we see a much broader trend that will evolve digital communities to virtual worlds and the 3-D Internet, and much more sophisticated social computing tools. To provide perspective, the general digital communities landscape today takes two forms.[2]

The first type of digital community focuses on business value, for example, providing a platform for learning, developing software intellectual capital, or enabling a type of commerce exchange. Individuals participate because these communities attract and retain members by providing real or perceived value. Table 2 lists several digital communities that offer business value.

Table 2 Digital communities offering business value

Business value	**Description**
MIT Open Course Ware and the OCW consortium	1800 MIT courses content online currently
Merlot	Open source consortium where teachers post their content
Moodle	Open source course management system; business partners service local installations
Sakai	Open source product to support teaching and learning
Wikipedia, Curwiki, Wikieducators	Collaboration to harness collective intelligence

[2] See the *IBM Research Global Technology Outlook* document, which is available from your IBM Representative.

Business value	Description
Google Scholar	Web search engine that indexes the full text of scholarly literature The GS index includes most peer-reviewed online journals of the world's largest scientific publishers. It is similar in function to the freely available Scirus from Elsevier, CiteSeer, and getCITED. For more information, see "Google Scholar" at: http://www.scholar.google.com/
Zoho	Community collaboration productivity tools (spreadsheet, word processing, and so on)
Amazon	First highly successful virtual retailer that built communities into the site with community reviews, discussions, and rating
Canadian Virtual University	Partnership of universities across Canada that offer over 2000 university courses
Virtual Global University	Organization that provides higher education on the Internet
HKVU	Online university jointly offered by The Hong Kong University of Science and Technology, City University of Hong Kong, Lingnan University, Hong Kong Institute of Education, and The University of Hong Kong
Phoenix	For-profit educational institution that specializes in adult education; the largest private university in the world, although fraught with critics of academics and faculty quality

The next type of digital community focuses on social value by providing a means to socialize and belong to a community based on its perceived social value. Table 3 lists several digital communities that offer social value.

Table 3 Digital communities offering social value

Social value	Description
Second life	Virtual world; free to join or pay to own land (subscription)
Xing	Professional directory search network
Ning	A platform for creating collaboration spaces
LinkedIn	A business-oriented social networking site that is mainly used for professional networking; as of April 2009, it had more than 40 million registered users, representing 130 industries; free to join; subscription for premium services
MySpace	A social networking Web site that offers an interactive, user-submitted network of friends, personal profiles, blogs, groups, photos, music, and videos; owned by Fox Interactive Media (FIM); advertising model[a]
Facebook	A social networking service for high school, college, university, corporate, non-profit, military and geographic communities primarily in English-speaking countries; advertising model
YouTube	A popular free video sharing Web site where users can upload, view, and share video clips; advertising model
Bebo (pronounced "bee-bow")	A social networking Web site that is designed to allow friends to communicate in various ways; over 22 million users; college oriented; photo sharing; advertising model

Social value	Description
Sametime®	A collaboration platform that provides peer-to-peer text messaging, file transfers, provide presence information (whereabouts and willingness/ability to chat) and record and archive chat histories; provides plug-ins for Voice over IP (VoIP) calling, screen sharing, multi-media Web conferencing, and intellectual capital sharing
Digg	A Web site to discover and share content from anywhere on the Internet, by submitting links and stories, and voting and commenting on submitted links and stories Only the most "dugg" stories are displayed on the front page.
SmallBlue	Social network analysis tool that shows the relationships between people based on instant message and e-mail traffic

a. An *advertising model* refers to getting revenue based on advertising receipts, which differs from a subscription model.

Notice that academic systems are not well represented in Table 3. Most education institutions are several years behind corporations in the application of social computing technologies. We discuss this in more detail in the sections that follow.

Technology enablers to support university collaboration

In the next 3 to 10 years, we see the elements for academic digital communities becoming more institutionalized, sophisticated, and formally integrated into a seamless institutional collaboration platform. This integrated digital community platform will consist of the following elements:

- Wikis
- Blogs
- Tagging
- Social network analytics
- Reputation and recommendation systems
- Enterprise instant messaging
- Telepresence and other videoconferencing
- Virtual worlds

Wikis are an increasingly popular means for making a Web site accessible to students and faculty to openly contribute or modify content, by using a simplified markup language. Blogs, which are Web sites that are usually maintained by a single student or faculty to provide regular commentaries and reviews about class content and assignments, are also making university inroads. Social tagging, also known as a *folksonomy*, is a way for individuals to "tag" content to create alternative information architectures to the hierarchical structure normally found in conventional Web sites. Their adoption will continue upwards in the next 5 to 10 years.

Social network software and analytics are tools for forming networks of relationships and contacts for the campus and beyond. In higher education, reputation and recommendation systems will assist in finding the best available resources for collaborative research projects and other assignments. Enterprise instant messaging will be adopted in classrooms and administrative offices on a much wider basis because it enables spontaneous discussions and makes classroom Q&A more efficient. Virtual presence (for example, videoconferencing) allows a person to feel as though they are present or to give the appearance that they are present in the same environment. Virtual presence is gaining adoption today at international universities with dispersed campuses, and this trend will continue. Virtual worlds will continue their inroads into immersive training. We discuss each of these in more detail.

Social network analysis

Students, administrators, and faculty rely on their personal network of friends and professional colleagues to obtain trusted information to filter, interpret, and make connections to others who might have similar research or personal interests. However, personal networks will not be sufficiently large or diverse when considering the reality of a large campus, with locations around the world. Social networking tools can fill this void by extending personal and professional networks in a globally-dispersed academic environment.

Social networking analysis capitalizes on people's networking behaviors specifically by using their social knowledge and artifact sharing. With social networking, the campus as a whole can benefit more effectively. If integrated properly into the community portal, the high-touch capabilities of social network tooling will have a rapid adoption curve among the 21st century educational institutions.

Social network analysis provides several features which will be in high-use for future education. The networking features of an IBM social network analysis tool called SmallBlue helps to show these high-touch capabilities (Figure 3).

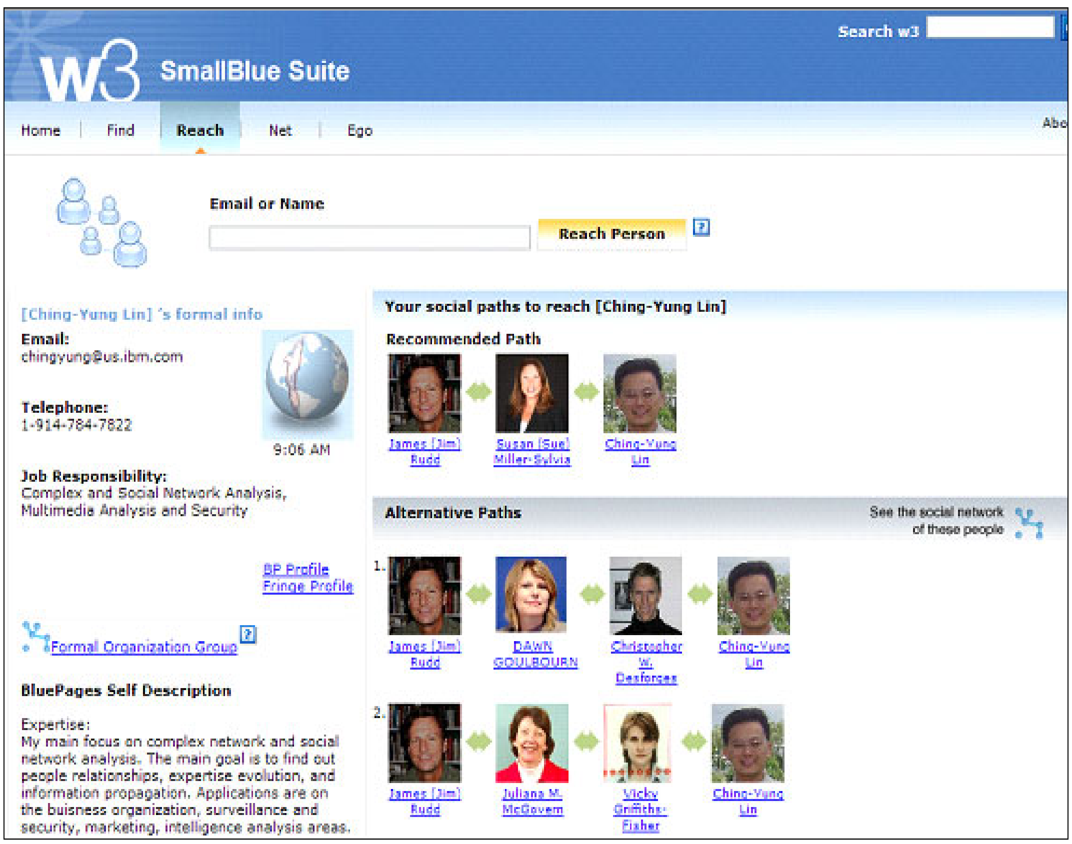


Figure 3 Example page from SmallBlue - The IBM social network analysis tool

Many other social networking analysis tools are commercially available today. In addition to SmallBlue, another social network analysis tool, called Xobni (Inbox spelled backwards) is available for free download and can be used for social network analysis for Microsoft® Outlook® mail.

Identification of knowledgeable colleagues

Through social networking analysis, students and faculty can search for people with a desired knowledge or skill across globally networked campuses. The search results are scoped to a specific area of research, country (region), or degrees of separation within a personal extended network.

How might social network analysis help you find knowledgeable colleagues? Consider an example where you want to interview Dr. Will Allen for a research project. Dr. Allen is an urban farmer, who has pioneered low-cost farming technologies and is a recent winner of the 2008 MacArthur genius grant. Although you do not know Dr. Allen, a social network analysis can identify a past student of one of Dr. Allen's professors whom you do know. Through these third-order relationships, you might able to arrange an introduction to Dr. Allen.

Academic reach visualization

Social networking analysis can provide a social dashboard that gives a consolidated view of a person's expertise, enabling the searcher to validate a person's expertise and determine their availability. A "reach" page includes a person's formal (or declared) expertise as defined within their campus profile, the communities to which they belong, and their recent public postings (that is, on blogs, forums, and so on). In addition, the reach page also shows the recommended and alternate social paths for reaching the person.

Social network visualization

Social networking analysis can also allow for large scale social network visualization and analysis capability. It displays the social network diagram for a given topic, keyword, or community, which can be used to find alternate experts as well as identify key influencers and brokers.

Social capital visualization

In addition, social networking analysis can provide a visualization of the social network of students and faculty as well as the social capital of each contact. *Social capital* refers to the number of new contacts that a user can be introduced to through their direct contact, including the geographical and organizational distribution of these new contacts. This visualization is private and personalized for each user.

Reputation and recommendation systems

Reputation and recommendation systems are a type of collaborative filtering system that typically integrate very large data sets involving collaboration among multiple raters and reviewers.[3]

Reputation systems use the collective intelligence of many individual reviewers to create ratings for other entities, such as people, businesses, or Web sites. Common reputation system examples can be "offline," such as Angie's List, which allows individuals to rate building contractors, handymen, and other service providers. Alternatively, such systems can be "online," such as what e-Bay offers, in which allows individual buyers and sellers can make decisions about whether they want to interact with a particular entity based on the prior experiences of others. Another example of an online reputation system is a Web site such as Bizrate.com, which provides store reputation ratings.

[3] James Thornton, Collaborative Filtering Research Papers at: http://www.jamesthornton.com/cf/

Recommendation systems differ from reputation systems in that individual users can make recommendations regarding content, such as class materials and the quality of online sources, rather than assessments of individuals. Examples of recommendation systems include Epinions (provides shopping recommendations), Digg (provides ratings of news articles), and iTunes (provides ratings of media). To see an example, visit the Digg Web site, which is available at:

http://digg.com/

A popular reputation site in academia today is *RateMyProfessors.com*. On this site, students can anonymously assign ratings to professors of American universities and others around the globe. Of course, there is much debate about whether students are capable of providing valid evaluations of professors.[4] However, the point remains that there is mass appeal of the reputation system approach, because the site currently contains six million ratings for more than half a million professors.

In the coming years, similar reputation and recommendation engines will have an eventual impact on reviews of academic articles and anonymous peer-to-peer reputation ratings of faculty, researchers, and other staff engaged at institutions. It might also substantially impact student/faculty acquisition and retention. We propose that these will be two tremendous investment areas for higher education.

Enterprise instant messaging

Enterprise instant messaging (EIM) is a form of real-time ad-hoc communication by two or more people based on typed text. Although instant messaging can be used for secure text transmissions, many corporations today have adopted it as a means of effective communication. Our investigation indicates that most educational institutions are significantly behind the adoption curve, although this will change in the coming 5 to 10 years.

Major vendors of enterprise instant messaging platforms are Microsoft (Microsoft Office Communications Server) and IBM (Lotus® Sametime, Figure 4). Both companies have introduced services to federate AOL, MSN®, and Yahoo onto their EIM platforms.

[4] Annalee Newitz, “Herding the Mob,” *Wired.com*, March 2007: http://www.wired.com/wired/archive/15.03/herding.html

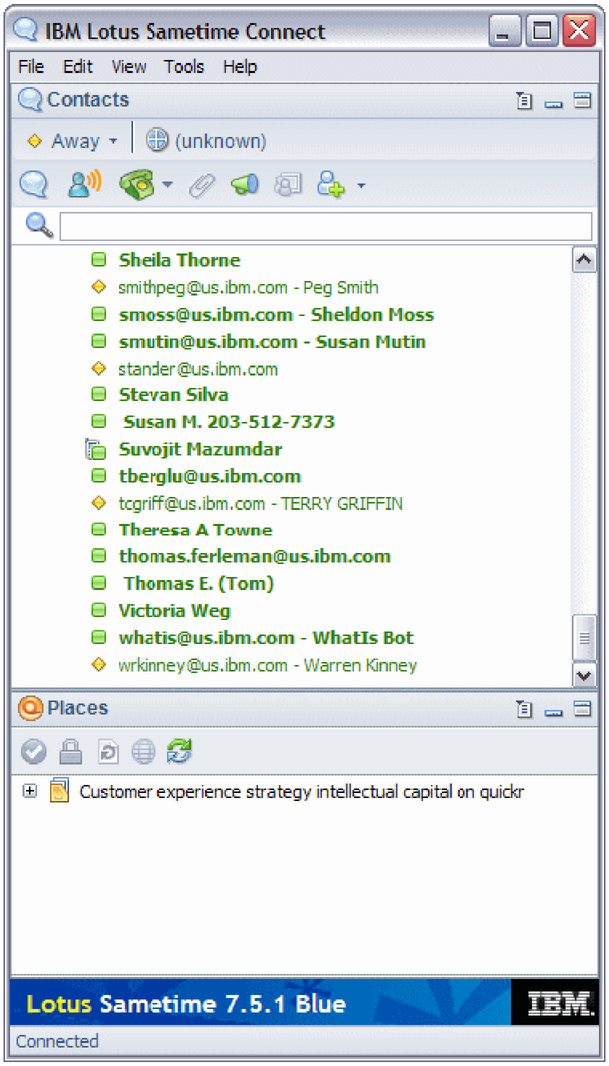


Figure 4 Example of an enterprise instant messaging contact list from Lotus Sametime

EIM platforms today include peer-to-peer text messaging as well as the capability to perform file transfers, set up one-to-many chats, provide presence information (whereabouts and willingness/ability to chat) and record and archive chat histories. In addition, EIMs, such as Sametime, provide plug-ins for VoIP calling, screen sharing, multi-media Web conferencing, and intellectual capital sharing. As can be imagined, this capability provides a much needed secure, real-time, and ad-hoc communication platform for large, dispersed campuses.

User-generated video

Some universities are opting out of investing in expensive video casting infrastructure and turning to grassroots services such as *YouTube* and *iTunes U* as a hosting platform for video content for their classes.[5] These sites accept a variety of common formats. Often times, they handle the intricacies of conversion and distribution more transparently than professional video content sites do. Because the costs of production and distribution for video have dropped to nearly zero, many of the barriers to video casting have disappeared.

[5] New Media Consortium and the EDUCAUSE Learning Initiative, *The Horizon Report: 2008 Edition*, ISBN 0-9765087-6-1: http://net.educause.edu/ir/library/pdf/CSD5320.pdf

Consider the following examples:

- Jonathan Rogness, a University of Minnesota professor created a video showing 3-D animation to illustrate Möbius transformations and posted it to YouTube. The video, which helps illustrates a complex mathematical concept in a simple way, has been viewed over 1.4 million times.[6]
- The Merlot Elixir (http://www.elixr.merlot.org) project uses digital case stories to encourage the adoption of exemplary classroom practices in higher education.
- MIT Tech TV (http://www.techtv.mit.edu) makes it easy for the MIT community to find and share video related to science, technology, or the community.
- Courses from the University of California, Berkeley, are available on its own specially branded YouTube channel.
- UMBCtube, a custom YouTube channel for the University of Maryland Baltimore County, allows the campus to blend community generated content with institutional video offerings.
- iTunes U offers courses from a variety of higher learning institutions.

Telepresence

Because 60% of all face-to-face communications is said to be nonverbal and many institutions have shrinking travel budgets,[7] collaborators are looking for additional mediums to supplement the faceless media of e-mail, instant messaging, and telephone communication.

One approach is through videoconferencing, and its high-realism counterpart, telepresence. *Telepresence* refers to the ability to make people feel as though they are gathered in a single place, even though they might be scattered geographically in multiple locations.[8] High-definition videoconferencing, a form of telepresence, is expected to be a key element of the classroom of the 21st century. Key vendors currently in this technology space are Cisco, Hewlett-Packard, Polycom, and Digital Video Enterprises. Telepresence differs from conventional videoconferencing in that individuals are displayed life-sized through a high-definition signal.

We anticipate that the classroom of the 21st century will require the following types of video solutions:[9]

- Room-based video systems

  These systems allow for a learning environment that is more immersive than Web conferences alone. These rooms will include online collaboration screens so that students and faculty can review learning materials in real time.

- Auditorium-based video systems

  Auditoriums will have large high-definition (200-inch+) projection screens to allow video conferences to be viewed by either large lecture-oriented classes or college forums.

---

6 Jonathan Rogness, "Möbius Transformations Revealed" YouTube, 03 June 2007: http://www.youtube.com/watch?v=JX3VmDgiFnY

7 Edward T. Hall, *The Silent Language*, Anchor, 03 July 1973, ISBN-10: 0385055498.

8 Carl Weinschenk interview with Ira Weinstein, "Telepresence: Beyond Video Conferencing," *IT Business Edge*, 09 March 2007: http://www.itbusinessedge.com/item/?ci=24842

9 Henry Dewing et al., "Video Conferencing Rises Again: New Business Imperatives And Technology Create Promising Market Opportunities," *Forrester Research*, 30 March 2007: http://www.forrester.com/Research/Document/0,7211,41328,00.html

- PC-based video systems

  In addition to the need for room-based and auditorium-based videoconferencing solutions, but there will be a need for a common PC-based solution. Standardized PC video lets constituencies work face-to-face and provides more of a personal touch when collaborating, than instant messaging, text messaging, or telephone conversation alone offer. Providers of public, internet-based personal videoconferencing, such as Skype, are helping to accelerate the adoption of these services.

- Telepresence

  Telepresence refers to the degree a person feels immersed into a situation. For example, as the size of a screen increases, one's sense of subjective mental immersion in the situation also increases. High-definition-quality displays, custom room designs, and life-size representations of others give participants the feeling of being collocated. Telepresence will benefit people around a globally-linked campus especially in those cases when body cues are important in communication. Consider the following examples:

  – Administrators can interview a job candidate for another location and vice versa without requiring travel on the part of the candidate or administrators.

  – Faculty members can participate in a thesis defense at another college campus.

  – Administrators spread among satellite campuses can collaborate on budget planning and other administrative team activities.

  – Researchers can collaborate with colleagues at other campuses on a regular basis without losing time related to travel.

Figure 5 Typical telepresence configuration

In the future, telepresence systems will be built using IP. To obtain maximum adoption by staff, the telepresence system will need to be extremely easy and transparent to use and integrated into the campus' community platform and other real-time aware systems. Ease of use will improved greatly through activity-based wizards. Such wizards will allow the user to select one button to set up the entire environment. For example, the user can take advantage of activity-based wizards that focus on frequently performed activities such as "Show a video," "Show this PowerPoint®," or "Show view of Singapore class room," rather than individual device setup. The ease of use will also improved greatly through the use of real-time aware technologies such as RFID, which allows autonomic environment setup based on sensing the presence of faculty, staff, or students.

Holographic videoconferencing

In 2008, Musion and Cisco demonstrated “holographic videoconferencing.” This demonstration showed an integration of Musion’s 3D holographic display technology with Cisco’s TelePresence’s system to create the world’s first real-time virtual presentation that connected Bangalore, India, with San Jose, California, in the United States. In the example, a presenter was live on the Bangalore stage in front of a Bangalore audience having a live “face-to-face” discussion with presenters from San Jose.[10] Holographic videoconferencing will be a mainstream pedagogical tool in the future.

Virtual realities

In the past, learning typically occurred in groups with real-time interaction and synchronous learning. Students benefited from networking and peer-to-peer interaction at a rudimentary level. However in a geographically-distributed educational community, getting people together is not always possible. As such, in the future, virtual realities will be used heavily to enable collaborative learning within distributed teams. Through these technologies, learning will be enhanced with an engaging interface and realistic simulation of cultural, historical, scientific situations while maintaining the advantage of a large repository of information.

The following emerging technologies warrant further discussion:

- Virtual worlds
- Massively multiplayer online gaming environments

A growing society is emerging around virtual worlds. More than 60 schools and universities have a presence in Second Life, the most in the last several years. They join a population that includes real-world business people, politicians, entertainers, and more than 800,000 other “residents” of the virtual world.[11]

Virtual worlds have gotten a lot of attention over the last several years because of Second Life. Developed by Linden Research, Second Life is an Internet-based multi-user virtual world where people can interact with each other through the use of an “avatar,” their personal representation in the virtual world space. Pure virtual worlds such as Second Life, There, and Active are not games per se. Rather they are platforms that can be populated with content to support any context.

Advantages of virtual worlds for education

Virtual worlds hold promise for education application, because they allow people to interact in a way that conveys a sense of presence that is not available in other contexts. The worlds can be inhabited by thousands of people simultaneously, providing a virtual conference setting.

Virtual worlds contain many elements of social networking, offering a feeling of connection and the ability to share rich media in real time. In addition, these social aspects lend the virtual world to role playing, scenario building, and allowing students to assume other roles (for example, astronaut, physician, and chemist) without incurring real-world consequences. Since virtual worlds are general, rather than contextual, they can be tailored to any subject or area of study. Artifacts and locations can be realistically rendered, and scale (from nano to cosmic) can be manipulated to best serve the learning context.

Virtual worlds for education have been used for immersive training, developing civic participation, visualizing real-time weather data, and modeling complex mathematical models.

---

[10] Musion Systems, Ltd., “Cisco TelePresence - On-Stage Holographic Video Conferencing: World’s First Live Holographic Video Feed from California, USA to Bangalore, India”: http://www.musion.co.uk/Cisco_TelePresence.html

[11] Gregory M. Lamb, “Real learning in a virtual world,” *Christian Science Monitor,* 05 October 2006: http://www.csmonitor.com/2006/1005/p13s02-legn.html

Examples of virtual worlds

The following examples indicate how virtual worlds have been used for education:[12]

- Bradley University offers a course in Second Life on field methods research.
- The schools of journalism and architecture at the University of California, Berkeley, are collaborating on building a re-creation of the 1940s jazz scene on 7th Street in Oakland in Second Life.
- A Harvard University class "CyberOne: Law in the Court of Public Opinion" gathers in an "outdoor" amphitheater, then "goes inside" a virtual replica of Harvard Law School's Austin Hall, and completes assignments from all over the digital world. Anyone with a computer connection can take the course for free. Students are participating from as far away as South Korea and China.
- BMW, the auto manufacturer, uses virtual worlds to teach auto repair.
- Manpower, the staffing agency, uses virtual worlds to help job candidates better prepare for interviews through role playing.

Massively multiplayer online gaming for education

Massively multiplayer online (MMO) Gaming (MMOG) is a global phenomenon, with over 16 million active subscriptions worldwide.[13] Such games as World of Warcraft, Halo®, and Lineage have captured the imagination of online players young and old (but mostly young and mostly male). MMOG is typically conducted in a highly immersive virtual world environment, bringing players together in goal-directed or discovery-based activity. The activity can be both collaborative and competitive and is often tied to a theme. However, MMOGs can also be built on simple graphical interfaces and even text-based games (called a *multi-player* "*dungeon*," or MUD, after "Dungeons and Dragons").

MMOGs are different from virtual worlds because they provide context, typically providing a goal to the player. The virtual worlds platform does not provide a goal-directed platform. The expansion of gaming beyond entertainment is often called *serious gaming*. Two examples of this educational gaming are two IBM projects. The first is the INNOV8 program, which brings together business and IT students to better understand the effects of an entire business ecosystem. The other, PowerUp, is a 3D engineering game for middle and high school students that focuses on energy, engineering, and diversity to generate clean energy while racing to save the planet from ecological disaster.

Advantages of MMOGs

MMOGs offer the following advantages:

- Can engage with students and others in large or small groups worldwide in an immersive online environment
- Provide the opportunity to create a mentoring environment between experienced and inexperienced players
- Provide team learning experiences through the creation of game environments that can foster both competitive and cooperative learning between and within teams

Disadvantages of MMOGs

Although interest in educational MMOGs dates back 10 or more years, the disadvantages of MMOGs are that they are difficult, time consuming, and expensive to produce. Steps are being taken toward making it easier to develop this kind of game. Open source efforts by WorldForge (`http://www.worldforge.org`), for example, and low-cost engines, such as Multiverse (`http://www.multiverse.net`), might be successful in lowering the barrier to development of these complex games.[14]

---

[12] See note 5 on page 14.

[13] Mogchart.com, "An Analysis of MMOG Subscription Growth": `http://www.mmogchart.com/charts/`

Open platforms

Just as consumer choice will lead to open mobile computing platforms, student choice will also ultimately drive educational institutions to be more open and collaborative in providing services. Students will demand that they can compile a variety of learning experiences from multiple institutions and providers into an aggregated and cohesive learning program that meets their needs.

Hastening this change is the emergence of the cross-institution personal learning path, which provides an aggregated view of a student's life-long learning experiences and accomplishments. However, to make the personal learning path a reality, much must be accomplished in creating an open and interoperable standard. While several commercial vendors currently offer portfolio solutions into the market, a single dominant platform has yet to emerge. We see open technologies between institutions as the most effective way to meet this need. With further adoption of open technologies, the notion of a cross-industry learning program will become a reality in the future.

Common standards will provide a framework for exchanging data and services across organizational boundaries in a heterogeneous technology environment. Agreement for how this information will be securely shared between institutions must still be established and universally adopted. The IMS™ Global Learning Consortium, a nonprofit organization that creates standards for learning, has created an ePortfolio standard that offers a start. However, it is not broadly implemented. To make interoperability a reality in the future, education at all levels must embrace three key open technology trends:

- Service-oriented architecture (SOA)
- Open platforms
- Integrated data

Service-oriented architecture

Many IT executives in education around the world have likely heard of SOA or have probably been on the receiving end of presentations by vendors selling SOA solutions. But what is SOA, and how might education in the future ultimately see benefit from it?

In its simplest form, SOA is a technology framework that packages business processes into consumable services to be used by others. It hides the underlying technical complexity of the business process data and functionality. It exposes the business service through a standardized interface. It holds great promise for education because many institutions are reaching the point where there are so many applications and interfaces, that making changes to one system often times impacts many others, turning supposed small projects into expensive, complex, and lengthy efforts. By using SOA to "wrap" existing business process data and functionality, departments and institutions can potentially transform their IT efforts without funding huge, risky rip-and-replace projects, by enabling functionality in reusable chunks.

When considered in the context of the personal learning path experience, SOA allows institutions to support interchange of services and data without direct dependency on each institution's idiosyncratic implementation of its underlying business process. Instead, with SOA, individual learning services provided by these heterogeneous institutions can function with complete transparency to the student and other institutions so that portable e-portfolios are possible.

[14] New Media Consortium and the EDUCAUSE Learning Initiative, "The Horizon Report: 2007 Edition," ISBN 0-9765087-4-5: http://www.nmc.org/pdf/2007_Horizon_Report.pdf

For example, in today's environment, a request for a student's transcripts and learning artifacts require many individual communications with multiple education institutions and other learning providers. In contrast, with an SOA-enabled e-portfolio, students can simply access their collection of transcripts and authenticated artifacts using a persistent archive that is enabled by SOA-based e-portfolio participating institutions.

To this end, the IMS Global Standards body and the e-Framework for Education and Research have established best practices and standards to help the education take advantage of the SOA approach. Application vendors and open source communities are starting to adopt SOA concepts within their products. For example, Sakai, an open source community, has implemented a services-oriented model for their best-of-breed collaborative learning environment. Sakai is in production at over 160 institutions and is being piloted by over 200 more. It has the support of some of the world's most respected learning institutions and administrative application vendors including Sungard, Oracle®, and IBM.

Open software platforms

Open platforms, including *standards* and *open source software* (OSS), refer to technology environments that are developed by a community of developers, rather than a single vendor, and for which the source code is made available by a copyright license. With OSS, users can use, modify, extend, and redistribute the open source without cost.

A 2007 study by the Alliance for Higher Education Competitiveness (A-HEC) found that 57% of U.S. educational institutions use some form of open source infrastructure software (operating systems, web servers, databases, and so on). It also found that 34% have implemented open source application software (course management systems, file sharing, portfolio repositories, and so on).

Why will open platforms become even more important in the future? First, with the number, complexity and interdependency of campus applications growing, the cost of maintenance and upgrade is spiraling out of control. Second, many commercial products are not well tailored to education needs and are difficult to customize. Finally, consolidation in the IT industry in general is leading to unfair use by an increasingly smaller number of vendors.

The model of open source software for learning can be based on replicating successful projects in other IT industry open source initiatives. For example, Apache Foundation, a community of open source projects, has nearly two-thirds of the market for Web servers, approximately 10,000 contributors, and an organization to govern the software's development. Linux, the open source operating system, is used in 20% of computers, has thousands of contributors, and has a highly evolved development process. Moodle, an open source education application has been installed in over 10,000 sites (including both secondary schools and higher education) and has nearly 200 contributors worldwide. Again we mention the success of the Sakai Project, which is in use by 160 institutions around the world.

Integrated data

Governments have long expected their educational systems to produce qualified, skilled graduates for the workforce. In a rapidly changing and dynamic global society, education is asked to become more agile, responsive, and aligned to societal goals.

Decision makers must have insight into the state and direction of educational programs. Managing the performance of the system against defined outcome measures requires data at both an aggregated and individual student level view. A transition will occur over the next decade where business intelligence systems will be used increasingly to mine student data to provide better views into student performance. Also, data that represents a lifelong view of an individual's performance and achievement will be more easily, securely, and readily shared across institutional boundaries.

The single view of the student

School systems often lack a central data warehouse and business intelligence system where student, instructional, financial, and human resource (HR) information is united. Much of the data crunching today is either based on spreadsheets or paper, which are methods that preclude efficient data merging, synthesizing, and reporting. In addition, valuable data to provide insight to a student's performance is often outside of the educational system. For example, other governmental social service agencies have data that can provide a more complete view of a student's well being, such as financial assistance to the family, foster care status, and housing information.

In the future, education will work to better integrate performance management data such as in the following examples:

- Programs, policies, or other factors that can best predict student success
- The programs, policies, or other factors that have no influence at all, or worse, which programs and policies will have a detrimental impact on success
- The key factors that portend low performance
- The impact that classroom grades, attendance, and discipline events have on test performance; whether these are one-to-one relationships or we can build a predictive model that provides a multivariate understanding of these variables and their combined effect on test performance
- The investments that are improving results and how much more can we invest

To make the single view of the student a reality, governments and educational institutions must work together to combine their data so that these predictive analytics can be conducted.

How to make it happen

Integrated data and analytics provide the tools that are necessary to combine data sets and address hypotheses about how the contribution and interaction of multiple factors can affect performance results. By adding a time component, historical data can be tracked showing how results are trending over time. Analytics are being used on several dimensions of student performance to give teachers and administrators insight on a student's progress and trends. By combining data from multiple education institutions, schools can gain a class view of student performance, allowing them to make informed decisions about those elements of the classroom curriculum and experience. In addition, the data can be used to inform teachers about those elements to review in the classroom to help replicate success. [15]

In addition to grades and test performance, data integration and analytics can be used to determine how repeated absences and disciplinary actions impact individual performance. They are also used to determine the side effects of such absences and actions on the classroom and the school at large. Insights gleaned from analytics can help school districts intervene proactively to restore students' attendance and steer them back on track for learning.

[15] See *Reporting and scorecarding in primary and secondary education*, which is available at: http://www-01.ibm.com/software/data/cognos/solutions/education/library.html

Monitoring exceptional students is also an area where data integration and analytics plays a key role in the educational continuum. Both exemplar students and students who are falling behind their peers need special attention in order to encourage a continued interest in learning and to mitigate failure. While good teachers can instinctively spot exceptional students, they do not have the time, resources, or mandate to follow an individual student's progress across subjects from year to year in relation to their peers.

For example, a leading U.K. university realized that it needed a better way to manage student life-cycle data. Seven faculties and multiple departments each held different types of student information, including admissions, fee payments, registration, and exam results. There was no way to retrieve a student profile that contained all information for that student. The university was also accountable to government agencies. A new national program called *Lifelong Learning* was requesting data for its database of individuals' career-long records.

Built on a single architecture, data integration and analytics software from Cognos® helped the university meet the widespread need for accurate, comprehensive data. Now the school gathers all of its data into a single metadata layer that provides real-time, online, easy to-use student and financial information. Centralized and streamlined reporting has cut the reports that are needed by half.

Data gathering and reporting at the department of education level is typically fraught with difficulty because of incongruent data formats. With a single view of the student, different data types from the various districts can feed into a single, integrated reporting environment at the local level. School districts can standardize on a single format for input data, making it easier for administrators to report on and analyze student and school results across the department. This helps to validate spending decisions and focus attention where it is needed.

In the future, a single view of the student will also better enable reporting of student performance at the national level. Integrated student data and analytics will promote consistency and accuracy to the mountain of test performance data. Integrated data ensures that every student's record contains the same information, and that records can be combined and compared either in whole or by demographic slices such as gender, economic status, or language proficiency. Educational performance management helps make mandatory compliance reporting significantly easier, especially as it relates to obtaining state and federal funding.

Future challenges

Open platforms have challenges to address in order to become dominant drivers for education in the future. First, the industry must resolve the question of how services will be defined, governed, managed, and reliably provided. Historically, education service providers have chosen to define proprietary models for applications, with interoperability occurring only at the structured data level.

Second, there is the issue of the economics of an SOA environment. Often in education, each application traditionally has had its own maintenance and support costs, and the "owner" department is responsible for paying them. Because SOA makes business functionality available as Web services across the institution and potentially also across external organizations, new models for pricing and recharging must be created between provider and consumer.

For OSS, issues regarding ongoing maintenance, support and enhancements must be addressed. Effective models that support Linux operating system and Java™ development tools have emerged that use commercial providers for ongoing and long-term stability of the software.

Industry standards will continue to be essential if educational institutions are to embrace SOA and OSS. Some work has already been done on standards enablement, and this trend will continue. Additionally, many organizations are working on standardizing the exchange of student data. The Post Secondary Electronic Standards Council (PESC), for example, has already developed high school transcripts, college transcripts, and academic records. In addition, it is working on standards for admission application, course catalogues, national test score reporting, and student aid.

The Schools Interoperability Framework Association (SIFA) is a non-profit organization that includes over 300 software vendors, school districts, state departments of education, and other organizations active in primary and secondary (pK-12) markets. It originates in the U.S. and is broadening to other countries to define standard specifications for student data including food services, grade books, and human resources

This transformation requires tremendous and sustained innovation. An SOA offers the best opportunity to direct innovation and avoid “re-inventing the wheel.” A common service delivery model, data exchange standard, and open source platform for learning provides the core basis for delivering services to students that better allows their unique, individual path in the education continuum.

Although many of the challenges in making the single view of the student a reality are technical, such as common interoperability standards, the vast majority of the challenges are governance and policy related. Specifically, the promise of integrated data to produce a single view of the student must also address these policy challenges:

- Invest in accountability systems based on a model of integrated data and analytics that provides educators with insights on what happens to students after they complete their education, transfer to other universities, or accept jobs.
- Use the single view of the student to discern whether students truly have the necessary skills to gain and maintain employment and if not, use insights gleaned from analytics to identify remedial action, both at the school and individual student level.
- Support policy that rewards evidence-based educational transformation. Enable governments and educators with the tools that allow them to gather data, analyze that data, and create policies based on firm knowledge about the policies that will create desired outcomes.

Cloud computing

Cloud computing is engineering as a truly disruptive technology. In fact, among the underlying technology trends that we mention in this report, the likelihood of cloud computing having a transformative rather than an evolutionary impact is probably the highest of the three trends.

There is much hype about cloud computing, yet cloud computing means different things to different people. After considering many definitions, the definition proposed by Forrester Research makes the most sense when considering cloud computing in terms of an Internet scale data center:

> A pool of abstracted, highly scalable, and managed compute infrastructure capable of hosting end-customer applications and billed by consumption.[16]

Cloud computing is different than traditional hosting or software as a service for the following reasons:

- An abstracted infrastructure

  The cloud computing model is premised on standardization of the infrastructure and use of abstraction layers that allow the fluid placement and movement of services. Cloud computing requires a flat implementation of commoditized scaled-out server hardware that, for some clouds, serves as both compute and storage infrastructure. The infrastructure enables the cloud and is decided upon solely by the cloud vendor. Educational institutions cannot typically specify the infrastructure they want, which is a major shift from traditional hosting.

- Fully virtualized

  Nearly every cloud computing solution abstracts the hardware with server virtualization. The majority employ an open source hypervisor (for example, Xen) to help keep costs low.

- Dynamically configurable infrastructure software

  Most clouds employ infrastructure software, such as 3Tera, that can add, move, or change an application with little, if any, intervention by administrators.

- Pay by consumption and without long-term contracts

  Most cloud implementations charge by actual use of the resources in CPU hours, gigabits consumed, and Gbps transferred, rather than by the server or a monthly fee. The pricing is typically much lower than found in a typical IT shop, nor is there an expectation of long contractual arrangements. For example, the minimum contract for Amazon's elastic compute cloud (EC2) is for one hour. This makes clouds an ideal place to prototype a new service, conduct test and development, or run a limited-time campaign without IT resource commitments.

- Application and operating system independent

  In most cases, cloud architectures support nearly any type of application that the customer might want to host as long as it does not need direct access to hardware or specialized hardware elements. Most cloud implementations today support Linux, with others supporting Windows®, MacOS, and Solaris™.

- No software or hardware installation

  Customers tap into a cloud just as they would any remote server. All they need is to log in. No software or hardware is required at the customer end or specialized tools are needed to deploy an application. A person can select a cloud on the basis of application, operating

[16] James Staten, "Is Cloud Computing Ready For The Enterprise?" *Forrester Research*, 07 March 2008, http://www.forrester.com/Research/Document/0,,44229,00.html

system, database, or stack (for example, Linux, Apache, MySQL™ and PHP (LAMP)) or create an image from scratch.

Advantages of cloud computing

Cloud computing addresses a common IT problem, which is the need to address ever changing capacity requirements that might require investment in new infrastructure, training new personnel, or licensing new software. Cloud computing encompasses any subscription-based or pay-per-use service that, in real time over the Internet, extends the existing capabilities of IT. Cloud computing offers the following advantages:

- Superior economics

  The leading providers of cloud solutions (such as Google, Amazon, and IBM) buy so much server, storage, and other data center equipment. As a result, they have an enormous amount of negotiating power when it comes to hardware pricing, software licensing, and support contracts. Imagine the discounts and white glove treatment that can be attained if server orders in lots of 10,000 can be made.

- Expertise in handling dynamic workloads

  The leading cloud solution vendors have invested in management and administration tools that enable them to spread applications across thousands of servers and scale them quickly. They have developed best practices so that infrastructures can be optimized to accommodate new services quickly and without disruption.

- Expertise in dynamic capacity management

  The closely monitored infrastructure consumption of each application allows for greater productivity.

- Consumption-based cost tracking

  The tight mapping of IT resource consumption by application determines the margins on the services that they provide.

Types of cloud computing

There are several different variations of the cloud paradigm. They range from managed service provisioning, to Software as a Service, to an eventual future target of what is being called the *Integrated Internet*.[17]

The following types of cloud computing are available:

- *Managed Service Providers* (MSP) provides an application to IT such as application monitoring or virus scanning. One of the oldest forms of cloud computing, a managed service is basically an application exposed to IT rather than to users. Managed security services delivered by SecureWorks, IBM, and Verizon fall into this category, as do such cloud-based anti-spam services as Postini, which was recently acquired by Google.
- *Software as a Service* (SaaS) delivers an application to a customer. This type of cloud computing delivers a single application through the browser to many customers by using a multi-tenant architecture. On the customer side, there is no up-front investment in servers or software licensing. On the provider side, with just one application to maintain, costs are low compared to conventional hosting. Salesforce.com is the best-known example among enterprise applications, but SaaS is also common for HR applications and has worked its way up to enterprise resource planning (ERP), with such players as Workday. In addition, there are SaaS “desktop” applications, such as Google Apps and Zoho Office.

[17] Peter Wayner, “Cloud versus cloud: A guided tour of Amazon, Google, AppNexus, and GoGrid,” *InfoWorld*, 21 July 2008: http://www.infoworld.com/article/08/07/21/30TC-cloud-reviews_1.html

- *Service commerce platforms* provide a service to consumers. A hybrid of SaaS and MSP, this cloud computing service offers a service hub with which users interact. This type of cloud computing is most common in trading environments, such as expense management systems that allow users to order travel or secretarial services from a common platform that then coordinates the service delivery and pricing within the specifications that are set by the user. Well-known examples include Rearden Commerce and Ariba.
- *Utility computing* delivers storage and virtual servers to IT. Although this type of cloud computing is not new, it is offered today from Amazon.com, Sun™, IBM, and other companies that offer storage and virtual servers that IT shops can access on demand. While this utility computing is typically used for non-mission-critical applications, it is thought that it will eventually replace parts of the data center.
- *Web services in the cloud* delivers Web APIs to developers. While this type of cloud computing is closely related to SaaS, Web service providers offer APIs that enable developers to exploit functionality over the Internet. The APIs range from providers who offer discrete business services, such as Strike Iron and Xignite, to the full range of APIs that are offered by Google Maps, ADP payroll processing, the U.S. Postal Service, Bloomberg, and even conventional credit card processing services.
- *Platform as a service* (PAAS) delivers a development environment to an IT shop. This is another SaaS variation. This form of cloud computing delivers development environments as a service. You build your own applications that run on the provider's infrastructure and are delivered to your users by the Internet from the provider's servers. These services are constrained by the vendor's design and capabilities, so that they do not provide complete freedom, but provide predictability and pre-integration. Prime examples include Force.com from Salesforce.com, Coghead, and the new Google App Engine. For extremely lightweight development, cloud-based mashup platforms abound, such as Yahoo Pipes or Dapper.net.
- *Internet integration* is an Internet-based service bus. Cloud computing today might be more accurately described as "sky computing," with many isolated clouds of services that IT customers must plug into individually. As virtualization and SOA permeate the enterprise, the idea of loosely coupled services running on an agile, scalable infrastructure should eventually make every enterprise a node in the cloud (the Internet).

The integration of cloud-based services is in its early days. OpSource, which mainly concerns itself with serving SaaS providers, recently introduced the *OpSource Services Bus*, which employs in-the-cloud integration technology from a little startup called *Boomi*. The SaaS provider Workday recently acquired another player in this space, *CapeClear*. CapeClear is an enterprise service bus (ESB) provider that was edging toward business-to-business (B2B) integration. Grand Central was another small company that aimed to be a universal "bus in the cloud" to connect SaaS providers and provide integrated solutions to customers. However, it was ahead of its time and dissolved in 2005.[18]

[18] Ibid.

Challenges to cloud computing

There are several challenges in making cloud computing a pervasive computing model for education:

- Concerns about standards

  The industry must standardize to reach the point where images are not specifically written for one hypervisor. Ideally, there will be common formats within the image so that they can be activated anywhere.

- Concerns about stability

  Most cloud vendors today do not provide availability assurances. Service-level agreements (SLAs) are generally nonexistent.

- Concerns around security

  Many enterprises say they do not use clouds because the services are less secure. However, the reality might be the opposite. Hosting companies that are expanding into clouds often identify security as one of their core competencies, where it is more a necessary evil for most enterprises.

- Lack of commercial ISV support

  Given that most clouds are unique infrastructures, most commercial operating systems and applications are not certified on these platforms. Because the infrastructures are virtualized, licensing is another issue.

- Little geographic locality

  With the exception of Akamai and Layered Technologies, no cloud vendors will place an application in a specific geography. In fact, most do not have geographic coverage. Amazon EC2 does, but does not indicate where an application is located geographically, nor can you request a specific geography today. Some government-specific regulations, especially in Europe, require that services or customer data be retained within a country's borders, and noncompliance is not an option.

- Difficult to initially set up and use

  The usage of clouds is relatively easy provided that a developer or IT administrator implements it. New businesses are forming, such as RightScale, to help the technically challenged, but the dream of business users provisioning the cloud for prototyping is a few years away.

- Not geared to large enterprises

  Most clouds do not allow enterprises to embed security and management agents and monitors. For example, Amazon EC2 is not Payment Card Industry (PCI) standards-compliant. Also, few vendors provide security or process compliance audits.

Education examples

Cloud computing academic initiatives are slowly emerging as institutions determine how best to move into this new model for computing.

For example, in the U.S., North Carolina State University, in collaboration with IBM, has created the Virtual Computing Lab (VCL) environment. The VCL cloud-based service allows users to remotely access a desired set of applications and environments over the Internet, by using a personal computer, notebook, or mobile device from anywhere, at any time. Software applications, operating systems, and environments are accessible. Access is instantaneous and offers a range of options from single desktops to classroom-sized labs, to collections of servers and storage, to high-performance computing clusters. The campus has announced plans to expand these same services to every primary and secondary student in the state.

In October of 2007, the University of Washington, Google, and IBM announced an initiative to address Internet scale computing challenges:

> ...The goal of this initiative is to improve computer science students' knowledge of highly parallel computing practices to better address the emerging paradigm of large-scale distributed computing. IBM and Google are teaming up to provide hardware, software, and services to augment university curricula and expand research horizons. With their combined resources, the companies hope to lower the financial and logistical barriers for the academic community to explore this emerging model of computing...[19]

Two years later, over 20 universities have joined the IBM and Google cloud initiative.

The following resources represent the IBM and Google cloud initiative at partner universities:

- Open source software is designed by IBM to help students develop programs for clusters running Hadoop. Hadoop is an open source implementation of Google's published computing infrastructure, specifically MapReduce and the Google File System.
- A cluster of processors run an open source implementation of Google's published computing infrastructure (MapReduce and GFS from Apache's Hadoop project.[20]
- A Creative Commons licensed university curriculum is developed by Google and the University of Washington that focus on massively parallel computing techniques that are available at the following address:

  http://code.google.com/edu/content/parallel.html
- Management, monitoring, and dynamic resource provisioning of the cluster are possible by IBM using IBM Tivoli® systems management software.
- A Web site encourages collaboration among universities in the program. The Web site will be built on Web 2.0 technologies from IBM Innovation Factory.[21]

Through this initiative, the companies hope to lower the financial and logistical barriers for the academic community to explore this emerging model of computing.

As open platforms and SOA become part of the prevailing computing model in the future, the idea of loosely coupled services running on an agile, scalable infrastructure should eventually make every institution a node in the cloud. Cloud computing is a long-running trend with a far-out horizon, and in the next 5 to 10 years, it will become a mainstay of the education computing environment.

[19] IBM Press Release, "Google and IBM Announce University Initiative to Address Internet-Scale Computing Challenges," 08 October 2007: http://www-03.ibm.com/press/us/en/pressrelease/22414.wss

[20] See http://hadoop.apache.org

[21] Scott Delap, "Amazon's SimpleDB and IBM's Blue Cloud™ Continue the Rise of Cloud Computing," *InfoQueue*, 17 December 2007: http://www.infoq.com/news/2007/12/simpledb

Creating Education for a Smarter Planet

The vision from IBM for the future of education integrates all of these enabling technologies to create a smarter way of delivering learning, administrative and research IT services to educational communities. The *Smarter Classroom*, which is a 21st century model for learning, removes the barriers of time and space for students of all ages. This model takes a systemic view of education, evaluating students in multiple dimensions throughout their lifetimes, equipping them with the skills and knowledge that they need to achieve academic success, and positioning them to contribute to employers, communities, and society.

The Smarter Classroom provides the following benefits:

- Learning environments that improve student achievement by increasing access to resources and tools for collaboration in an open environment according to individual needs, preferences, abilities, devices, and aspirations
- Student data environments that provide real-time information, insights, and strategies to teachers and faculty
- Open source applications, content, and standards to enhance cost-effectiveness and interoperability
- Student devices that deliver high functionality while reducing acquisition, support, and operational costs by centralizing services
- Cloud-based services and infrastructures that create a dynamic, green, and flexible desktop as well as IT environments that are built on world-class technologies, software, and integration services

In this section, we provide three scenarios that present the Smarter Classroom.

Primary School: Olivia

Olivia is a sixth grade student, awaiting her bus to school. On her personal digital assistant (PDA), Olivia edits a video story about a recent earthquake in Japan that she is working on with a student from the affected area. From her PDA, Olivia can access video, news articles, and other information about the earthquake to compile the article. While she works on the report, her assistant communicates continuously with a centrally located assessment service that records her activities and progress.

The assessment tool provides her teachers, parents, education specialists, and Olivia herself with progress tracking against objectives. The system can help tailor activities that will help speed and enrich her learning process.

At school, Olivia shares the news of the earthquake with her classmates, who become interested in the story and begin their own research. Her teacher is alerted to the class interest in the event and decides to adjust the lesson on physical sciences to incorporate more detailed lessons on seismic activity. Olivia and a classmate are teamed together in researching another earthquake in the last century in Alaska.

While reading the report aloud, Olivia's classmate has trouble with some of the unfamiliar, scientific words. A voice recognition reading program evaluates the fluency of reading, and alerts the teacher's PDA to the student's difficulties. The teacher then is provided with recommended activities for the student to practice reading and selects the appropriate activity to assign for that evening.

Later at home, Olivia and her father are reviewing her progress, and they have a question about a follow-on assignment from the earthquake report. They establish a video connection with her teacher and clarify the assignment. Her father recommends one of his colleagues to the teacher, a seismologist, as a subject matter expert for the next day's class.

Olivia's learning is integrated seamlessly into her formal and informal activities at home and in school. She has access to people, resources, and information around the globe to help create a personalized path for her learning. Her progress is tracked continually through the integrated assessment of her activities, so her learning is not interrupted by testing.

Higher Education: Dr. Kelly

Dr. Kelly is a faculty member at Global Networked University and is preparing for her class on the History of Western Thought. Dr. Kelly's university has many locations around the globe, and her current class has students in both the U.S. and in the Middle East.

In preparing for the class, Dr. Kelly ensures that she has her RFID campus badge, which gives her access to her personal data repository, systems, and archives from any device with access to the Internet.

She begins her class with a welcome by the president of the university, Dr. Winston. Because Dr. Winston is not physically in either the U.S. or Middle East location, he speaks to the class using a holographic telepresence system. While his 3D, virtual image is projected to both locations, he can see the participants in the two locations and respond to questions in a conversational mode.

Dr. Kelly begins the class by activating the interactive video wall using simple gestures that are recognized by the device. She projects her lecture materials, classroom-aware student information, and the live feeds from both class locations.

A Lecture Console provides her with a variety of data, insights, and resources that help inform that day's class activities. She can see on the console that her class is being recorded and indexed for easy cataloging and retrieval from the university's digital library. She also sees information about each student who attends the lecture, the student's progress, and the student's real-time interaction and participation. The students can interact continuously through the class using collaboration technologies and tools.

Dr. Kelly is able to have a global reach while providing personal attention to students. A centralized repository manages her teaching materials safely and securely. Her students create a dynamic learning community that is facilitated by collaboration tools.

Adult Learning: Debra

Debra is a medical technologist who is taking advantage of a government-sponsored educational program to train more workers in geriatric physical therapy. Her program allows her to continue her regular employment while participating in learning activities at home, at practicum in small group settings, and in clinical experience.

From home, Debra participates in a real-time interactive clinic with her classmates. They are preparing for the next day's appointment with an elderly woman who recently suffered a hip injury. The group collaboratively reviews the patient's records and develops a proposed course of treatment. As they review the case, Debra's PDA collects the information that is presented, as well as journal articles and background materials that will complement her learning activities.

Her supervisor asks Debra to demonstrate the correct method for assisting a patient with a hip fracture to begin walking. Using a virtual reality system, she can simulate the experience authentically and gain feedback on her techniques from her classmates and instructor.

After meeting with the patient, Debra presents her findings to her professor, who posts critiques, suggestions, and assessment to both Debra's, as well as her supervisor's, PDAs.

Without leaving her current job, Debra gains valuable skills that will serve the needs of her community. She weaves learning into the fabric of her life seamlessly at her convenience.

A roadmap for enabling a future vision

In the vision of the future, we imagine a world of interconnected education in which the following goals are possible:

- People routinely learn outside the classroom using the location, style, and device of their preference.
- Students are able to pursue a personalized path of learning and can document those experiences in a portfolio that follows them throughout their lifetimes.
- Teachers, learners, and administrators collaborate easily, although not necessarily face to face, and not necessarily in real time.
- Learning and administrative services are delivered across a virtualized, dynamic, cost-effective infrastructure.
- Life-long learning is integral to individual's careers and to the health of a region's economy

The power of connecting educational providers and having them interoperate creates dynamics for innovation in learning that we have not seen before. We have experienced the first examples where students are learning in more collaborative modes and where local administrators are discovering emerging performance issues in real time. We see college graduates supplying both a transcript for prospective employers and easily accessible portfolios of achievement.

How will the educational continuum of the future unfold? Institutions can take the following technology-based actions today to prepare for this transformation:

- Create an open technology infrastructure
- Create an open environment for integrated data and processes
- Create a network of collaborative and shared services through open research and open learning.

By focusing on these initial actions, enhance its value to the community and funders, through improved outcome, a highly skilled workforce, and innovation in the marketplace.

To learn more about our study in education and to see a full catalog of our research, go to the following address:

http://www.ibm.com/education

Other resources for more information

For additional information, see the following resources:

- Education for a Smarter Planet™: The Future of Learning (Executive summary)
- Education for a Smarter Planet: The Future of Learning (Executive Insights)

These document are available at:

http://www.ibm.com/education

The authors who wrote this guide

This guide was produced by a team of specialists from around the world working at the International Technical Support Organization (ITSO).

Dr. Jim Rudd is an IBM Distinguished Engineer and is the Practice Leader for IBM Interactive. You can contact him by sending e-mail to jimrudd@us.ibm.com.

Chistopher Davia is the Industry Architect for the Global Education team and provides the technical and architectural guidance to IBM solutions and offerings for schools and higher education clients. You can contact him by sending an e-mail to cdavia@us.ibm.com.

Patricia Sullivan is the Education Solutions Executive for IBM Global Education and leads the development of emerging offerings to schools and higher education. You can contact her by sending e-mail to pasulliv@us.ibm.com.

Thanks to the following people for their contributions to this project:

- Fran Bouchard, IBM Global Business Services®
- James Cortada, Institute for Business Value
- Javier Diaz, IBM Interactive as a collaborator
- Kevin Faughnan, IBM Academic Initiative
- Shervin Hawley, IBM Interactive
- Alex Kaplan, IBM Global Business Services
- Michael King, IBM Global Education
- Diane Melley, IBM On Demand Community®
- Jai Menon, IBM Global University Programs
- Sandy Nguyen-Huynh, IBM Interactive
- Mark Olson, IBM Global Business Services
- Kirsten Schroeder, IBM Global Business Services
- James Spohrer, IBM Global University Programs
- Dave Spurlock, IBM Global Business Services
- Robert Sutor, IBM Open Source and Linux
- Kevin Turner, IBM Global Business Services
- Robin Willner, IBM Global Communities Initiatives
- Barbara Wyse, IBM Interactive

IBM Global Education

IBM Global Education collaborates with educational institutions, researchers, and governmental agencies worldwide to create innovative business and technology solutions enabling continuous improvement in education. IBM Global Education brings a depth of experience to schools, colleges, and universities through our consulting services, products, and partner offerings. You can contact the authors of this document for more information.

About IBM Interactive

IBM Interactive is IBM Global Business Services' digital interactive agency that provides customer experience strategy, user research, Web analytics and assessments, and online creative design and development to IBM clients worldwide.

IBM Global Business Services

With business experts in more than 160 countries, IBM Global Business Services provides clients with deep business process and industry expertise across 17 industries, using innovation to identify, create, and deliver value faster. We draw on the full breadth of IBM capabilities, standing behind our advice to help clients implement solutions designed to deliver business outcomes with far-reaching impact and sustainable results.

Notices

This information was developed for products and services offered in the U.S.A.

IBM may not offer the products, services, or features discussed in this document in other countries. Consult your local IBM representative for information on the products and services currently available in your area. Any reference to an IBM product, program, or service is not intended to state or imply that only that IBM product, program, or service may be used. Any functionally equivalent product, program, or service that does not infringe any IBM intellectual property right may be used instead. However, it is the user's responsibility to evaluate and verify the operation of any non-IBM product, program, or service.

IBM may have patents or pending patent applications covering subject matter described in this document. The furnishing of this document does not give you any license to these patents. You can send license inquiries, in writing, to:
IBM Director of Licensing, IBM Corporation, North Castle Drive, Armonk, NY 10504-1785 U.S.A.

The following paragraph does not apply to the United Kingdom or any other country where such provisions are inconsistent with local law: INTERNATIONAL BUSINESS MACHINES CORPORATION PROVIDES THIS PUBLICATION "AS IS" WITHOUT WARRANTY OF ANY KIND, EITHER EXPRESS OR IMPLIED, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF NON-INFRINGEMENT, MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE. Some states do not allow disclaimer of express or implied warranties in certain transactions, therefore, this statement may not apply to you.

This information could include technical inaccuracies or typographical errors. Changes are periodically made to the information herein; these changes will be incorporated in new editions of the publication. IBM may make improvements and/or changes in the product(s) and/or the program(s) described in this publication at any time without notice.

Any references in this information to non-IBM Web sites are provided for convenience only and do not in any manner serve as an endorsement of those Web sites. The materials at those Web sites are not part of the materials for this IBM product and use of those Web sites is at your own risk.

IBM may use or distribute any of the information you supply in any way it believes appropriate without incurring any obligation to you.

Information concerning non-IBM products was obtained from the suppliers of those products, their published announcements or other publicly available sources. IBM has not tested those products and cannot confirm the accuracy of performance, compatibility or any other claims related to non-IBM products. Questions on the capabilities of non-IBM products should be addressed to the suppliers of those products.

This information contains examples of data and reports used in daily business operations. To illustrate them as completely as possible, the examples include the names of individuals, companies, brands, and products. All of these names are fictitious and any similarity to the names and addresses used by an actual business enterprise is entirely coincidental.

COPYRIGHT LICENSE:

This information contains sample application programs in source language, which illustrate programming techniques on various operating platforms. You may copy, modify, and distribute these sample programs in any form without payment to IBM, for the purposes of developing, using, marketing or distributing application programs conforming to the application programming interface for the operating platform for which the sample programs are written. These examples have not been thoroughly tested under all conditions. IBM, therefore, cannot guarantee or imply reliability, serviceability, or function of these programs.

This document, REDP-4564-00, was created or updated on September 10, 2009.

Trademarks