Cyberinfrastructure and the Brave New World of Higher Education

Katherine Kantardjieff, Department of Chemistry and Biochemistry &
Faculty Coordinator for Academic Technology

"I never teach my pupils; I only attempt to provide the conditions in which they can learn." – Albert Einstein

In this brave new cyber-enabled world of higher education, we have pedagogically rich cyber-infrastructure-mediated tools to create blended learning environments for our students. This article reviews some of these tools, and their potential pedagogical impacts. Ultimately, at issue is not the technology. It is about what you can DO with the technology to teach better and improve student learning.

Cyberinfrastructure

As a high school student in the 1970s, I was one of the first to have a pocket calculator. A Cascio that weighed at least a pound, it could add, subtract, multiply, divide, calculate logarithms and compute percentages. Wow. As a high school teacher from 1979-1982, my classrooms had computers. In particular, my chemistry class at Daniel Murphy High School in Los Angeles had a Texas Instruments 99-4 on which several students assisted me with Basic programming to create software tools for solving chemistry and physics problems. They also programmed it to play Christmas carols. ☺

The first IBM PC appeared in 1981, followed by the Apple Classrooms of Tomorrow™ (ACOT) in 1985. Since then, hardware and software have substantively evolved, providing us with transformative technologies: word processing, spreadsheets, desktop publishing, reviewing tools, citation managers, photo editing, presentation graphics, and the World Wide Web. With these transformative technologies have also come email, chat rooms, games, bootleg software and music, blogs, wikis, instant messaging, web conferencing, and ubiquitous computing initiatives. With the good, comes the bad; effective use and implementation of technology for purposeful e-learning requires knowledge of the technology (and a willingness to learn as part of one's professional development), a recognition of its strengths and limitations, and intelligent instructional design.

Cyberinfrastructure is defined by the National Science Foundation as "the coordinated aggregate of software, hardware and other technologies, *as well as human expertise*, required to support current and future discoveries". Indeed, learning and workforce development is a key strategic area identified by the NSF in its Cyberinfrastructure (CI) Vision for the 21st Century Discovery [1]. Technology cannot be taught without using technology. Although there is ongoing debate on content priorities and effective methodologies, with discussions about pedagogy, objectives, culture, educational priorities, and available resources, the fact remains that the future workforce needs to be trained with cyber-based methods and tools that they will be expected to design, deploy, adopt and apply to be competitive and globally engaged, whether they are future teachers, business executives, artists and musicians, writers, scientists or engineers.

The CI vision is a bold one that encourages the use of cyberinfrastructure-mediated tools to collaborate and communicate in ubiquitous learning environments and virtual organizations. Several objectives of the NSF CI vision are relevant to our missions and goals at Cal State Fullerton, in particular to change the organizational enterprise of learning, foster deployment and utilization of cyber-enabled learning and research environments, and study the evolution and impact of cyberinfrastructure on the culture and conduct of research and education. Merely "using" or "integrating" technology is not the end goal, because this is too broad and vague to guide purpose, implementation and assessment. We also must ask "What is the value added through using or implementing technology?", and also "What can we do now and/or better with a technology that we could not have done without it?" In considering these questions it is also important to remember (and dispel a damaging misconception): Utilizing and exploiting technology is NOT simply about teaching a computer class. Effective use and implementation of technology for education is not about the technology. It's about what you can DO with the technology [2].

21st Century Learning Environments Are Blended

Traditional classroom methods based in 19th century philosophies, with an emphasis on the "sage on the stage" format, create an often mechanistic, standardized, controlled and fragmented learning environment. Learning in the cyber-enabled age is about fully engaging students using a variety of learning methods through genuine collaboration, and by stimulating internal (not external) motivation to integrate learning into a life-long interest and endeavor. All of us need to re-examine and in some cases abandon our assumptions about student learning, artifacts of the 19th century that cannot meet the educational challenges of the 21st century in a cyber-enabled world. In today's cyber-enabled culture, we must produce in our students, who live in a world of flux, a knowledge workforce, capable of constantly absorbing and adjusting to new information, a workforce that is fully engaged in thinking, problem-solving, innovating and learning.

A blended learning environment is one that combines several different technologies as delivery methods, including collaboration software, web-based courses, electronic performance support systems and knowledge management practices. Blended learning also mixes various event-based activities including face-to-face classrooms, live e-learning, and self-paced learning. Thus, blended learning represents a spectrum of deliveries and activities, with one end being asynchronous, the other being synchronous, and various hybrid environments distributed across this spectrum. Regardless of where these environments fall in this spectrum, however, successful blended learning environments are characterized by a) stimulating creativity, b) involving learners, c) creating healthy e-learning environments, d) accelerating and enhancing learning, e) improving retention, f) building effective learning communities, g) improving technology-driven learning, h) saving time and money, and enjoying a return on investment, financially and operationally. Let's now look at a few of the technologies available for creating blended learning environments, including our campus' most recent acquisition, the web conferencing application, iLinc.

PowerPoint Pedagogy

Digital technology can enhance students' learning but only if our goals for student learning drive its use. Not all digital technologies are created equal. Some, by the very way they are likely to be used, have great potential for enhancing learning, while others do not. Case in point: Microsoft PowerPoint. PowerPoint is ubiquitous presentation software, designed by the business sector for making sales presentations. It is presenter oriented, or in the educational context, designed to promote the lecture; it is instructor-centered. If used in its default mode, it promotes passivity on the part of students. Whether they participate in the instructional process or not is incidental. Lectures are instructor-controlled in PowerPoint. Simply presenting a standard lecture with PowerPoint instead of overheads, a chalk board or white board tells you nothing about whether your students have comprehended what you have tried to communicate. In its basic presentation mode PowerPoint is not a pedagogical or innovative use of the technology. Moreover, providing PowerPoint outside of class as multimedia material does not structure the interaction of your students with the material during the time they are not in class, which is substantial.

Does this mean that PowerPoint is useless learning technology? Not necessarily. It is true that it can present material in a linear fashion, encourage students to passively absorb information, and be insensitive to students' background, interests, and level of understanding. However, the pedagogical value of PowerPoint, and any particular technology for that matter, will depend on the ways in which it is used. Each technology encourages particular strategies to its use, including PowerPoint.

Much of what we can do with PowerPoint can be done with white boards, overhead projectors, photographic slides and other similar technologies. Whether PowerPoint is better suited to a given task depends on the learning environment. But, here are some things to consider that PowerPoint can enable more efficiently than several other technologies combined, with the potential to provide you with more effective curriculum materials, and also to save you, the instructor, valuable time in the long run.

PowerPoint can utilize graphics more quickly, and perhaps render them better than you can sketch them. Concepts can potentially be made clearer with appropriate choices of color, contrast and text or font. Your presentation can be made available to students as a handout with plenty of room for students to annotate. Note taking and note making are critical skills for effective learning, and students tend not to take or make notes if you present them a complete, annotated set of notes. Your PowerPoint presentation

can be made available on your course website for further review, and with consistency, thus offering your students greater flexibility and accessibility in their learning endeavors. This can be the file itself, a pdf, or a recording you have made while delivering the lecture (and even pre- or post-lecture). Today, such recordings are easy to make with a headset or built-in microphone, using user-friendly software such as SnapKast, Camtasia Studio or Impatica. Judicious use of animations can clarify difficult concepts and reinforce conceptual understanding.

From an efficiency standpoint, PowerPoint lends organization; having your curriculum materials in electronic format such as PowerPoint facilitates creation of modified and updated presentations and efficient archiving of materials for future reference. It is also easier to speak from and to distribute well-organized slides and outlines than scribbled notes. PowerPoint is well-adapted to preparing lectures from materials heard at a conference or communicated on the web. It integrates with a word processor; in Office 2007, PowerPoint's "Slides From Outline" feature builds slides directly from Word documents. Use of PowerPoint templates also facilitates ADA 508 compliance, because these are used by various software tools to convert text into audio. PowerPoint.

PowerPoint can be pedagogically useful. It helps the instructor stay organized, keeps material legible and neat for students, and can easily provide skeletal notes to *support*, not supplant, student note taking and making. However, arbitrary use of PowerPoint, or any other technology for that matter, does not automatically win you glowing student evaluations of you don't know how to use it *to teach better*.

Instant Messaging

Instant messaging (IM) is a mind-boggling phenomenon. This simple tool for real-time text messaging and presence detection is a staple in our students' cyber-enabled lives, and it is changing decades-old messaging and communication patterns. While some may complain that this form of communication is impersonal, it is no less impersonal than email, and is in fact, synchronous in its typical usage. Without guidelines and structure that define appropriate use of IM, however, IM can be more of a distraction than a tool when used in education.

Students seem to prefer IM as a mode of communication to voice over internet protocol (VoIP), and if connected, will often engage in lively discourse, despite its seeming inefficiency. Thus, if we can devise challenging assignments that promote active involvement in learning and incorporate, at least in part, their preferred modes of communication, our students may find coursework at least as interesting as other activities competing for their time. Good use of technology to enhance a course can only serve to contribute positively to learning outcomes [3].

There are hundreds of ways we can synchronously communicate online with our students, including Blackboard's Virtual Classroom, Skype, etc. Instant messaging applications allow chats and file transfers, as well as white boarding and video messaging with a web camera. Why should we care as instructors? It is estimated that 74% of online teens use IM in comparison to 44% of adults, and most students use it several times a week, if not daily [4]. In addition, 37% of online teens have used IM to write something they would not have said in person, and 41% report using email and IM to contact teachers or classmates about schoolwork. How do they occupy their time outside of class? According to a national survey of college students, 31% of full-time college students devote more than 10 hours per week to informal conversations with other students [5].

So, does this all suggest we should be using IM in direct instruction? Yes and no. Students asked to evaluate the effectiveness of their online learning experience note that they value *asynchronous* discussions with their peers the most. Students are bored by reading screen after screen of text when an instructor tries to recreate a lecture online [6]. Brief instructional posts that stimulate thinking and discussion appear to contribute more to effective learning than posting a lecture online or using video or audio [7]. My own personal experiences with blended or hybrid courses strongly suggest that students do prefer chatting to VoIP, which they use to collaborate online, and even during virtual office hours. Accepted good educational uses of IM therefore include instructional sharing, group assignments with planned scholarly chat sessions or group brainstorming (providing an accessible record of student participation), office hours, online study sessions, help with homework, and as one form of backup communication when VoIP is poor or fails.

Course Management Systems

Course Management Systems (CMSs), and the newer generation Learning Management Systems (LMSs) are programs enabling instructors to teach or provide materials online. Popular programs familiar to

the reader are WebCT and Blackboard, which we have on our campus. Others include Moodle, Joomla, Drupal, eLeaP and CollegeBrain. CMSs are integrated systems creating a self-contained environment with many technical options for e-learning, blended learning, and delivery of online instruction. CMSs have been adopted largely out of convenience, to integrate campus computational resources, and to manage mundane tasks associated with instruction, particularly large classes. Questions have been raised about their pedagogical use, but few studies have been conducted on their effects on pedagogy, teaching and learning. Their standardization as a way to ease management issues may limit their pedagogical value [8, 9].

The pre-set organization of CMSs makes it easy for those less familiar with these tools to insert their content into pre-defined appropriate categories rather than to adapt the interface and translate their individual pedagogical style into a cyber-enabled environment. Whereas we typically envision accomplishing our pedagogical objectives in a temporal (weeks or semester) or topic framework, the default organization of Blackboard constrains the structure to content types and may actually limit faculty flexibility and creativity. CMSs to some degree reinforce the "sage on the stage" pedagogy by focusing on presentation of written documents and providing for complementary discussion by students. The construction of knowledge, also called the "guide on the side" approach [10], may actually be better supported by blogs, wikis and social networking web applications. Nevertheless, the newer generation LMSs do have added features that allow instructors to deviate from default settings by customization. Lack of knowledge about the technology makes it difficult to use LMSs pedagogically, particularly when faculty teaching online or hybrid courses do not make use of the web extensively or intensively in their own scholarship [11]. Those readers who are not digital natives or "web heads" may quickly find themselves overwhelmed. But, you are not alone. Those who consider themselves more experienced and innovative also become frustrated when faced with the pedagogical limitations of integrated CMSs.

Here again, the issue should not be about the technology, it should be about what we can do with the technology [12]. How can LMSs promote student learning and engagement? Faculty can learn to customize their LMS organization by week or topic, more reflective of a syllabus with defined objectives. Moreover, we can utilize free web applications that encourage social construction of knowledge and create component-based learning environments. Several additional applications to enhance constructivist pedagogy can be directly interfaced with LMSs. The latest in our campus' arsenal of educational technology tools, presently integrated into Blackboard, is iLinc, described in the next section.

Web Conferencing Technologies and iLinc

The pedagogical methods drawn upon in the blended learning environment can have a profound impact on the quality of the learning experience a student receives in a hybrid or distance learning course. Instructors should strive to stimulate learning and critical thinking rather than simply delivering content. The learning process will be more efficient and effective when interaction is integrated into the course rather than having students learning in the isolated monomedium. When students are required to participate and to lead discussions online, their active involvement creates a more engaging and effective learning environment. Rather than making the learning environment rote and isolated, a distance learning environment that is collaborative and interactive builds a true e-learning community, where the educational goals are palpable.

The concept of video conferencing was first developed in the 1960s by AT&T as a videophone. Innovations combining internet and multimedia technologies have evolved computer-based web conferencing tools, which are becoming one of the fastest growing learning technologies in delivering online education and training. Web conferencing applications provide tools for real-time, interactive communication between individuals, across distances, for virtual meetings, online collaboration and presentations. They can employ audio in the form of teleconferencing or VoIP, as well as video in the form of static graphics or streaming video from a web camera. While some may view web conferencing as a loss in the educational process, because students exchange a live instructor for a virtual one, the reality is that web conferencing is rapidly becoming the preferred mode for distance education. Students participating in programs utilizing web conferencing technologies have far higher completion rates than those using traditional paper-based distance education [13, 14].

Web conferencing technologies offer new ways to support learning in a blended environment by

facilitating interaction and discourse between geographically and sometimes temporally distributed learners and instructors. Participants can see each other, hear each other, and exchange electronic data [15, 16]. Web conferencing technologies provide students flexibility in attending classes remotely and accessibility if they must miss a session or have a disability. In addition, flexible scheduling allows for project-based instruction. Web conferencing technologies are also convenient for faculty and staff, allowing us to host and participate in in-service activities, department meetings and collaborations remotely. Students can also establish virtual meetings using these tools.

The keys [17] to successful implementations of web conferencing technologies into blended learning environments lie in a) understanding what is different about teaching at a distance; b) developing appropriate strategies for meeting student needs, as well as improving planning, organization, interaction and feedback; c) comprehending the phases of the process, including design, development, evaluation and revision; d) understanding and appreciating the need to evaluate, evaluation methods, and what to evaluate; e) knowing the instructional possibilities using the Internet; f) appreciating the advantages and limitations of various technologies; and g) perceiving the profiles of students and their development as remote learners. Web conferencing requires planning and practice. Familiarize yourself with the technology and any related ones you may be called upon to integrate or use as a backup. Immerse your students in the process and be clear about expectations and the rules of engagement. Students must be adequately prepared to actively involve themselves in the learning process. The ultimate goal is to focus on the participants, the content and the learning process, and NOT on the technology. Dealing with the technology is not a problem for the majority of our students, who are digital natives accustomed to similar forms of daily communication. If you are venturing into the brave new world of web conferencing, expect the initial phase to be exciting but sometimes tricky. Have a backup plan, or two. And, do NOT simply expect to plunge into a course full steam ahead. Run a pilot, or perhaps a parallel mode with an existing course. Remember, it is not about the technology, it is about what you can *teach and what can be learned* with the technology. And, please, share your lessons learned and best practices with other faculty colleagues.

Our campus recently acquired an enterprise license for iLinc, a web conferencing application consisting of several related tools for conducting different types of interactive sessions: LearnLinc, MeetingLinc, ConferenceLinc, and TestLinc. The grand vision for the next academic year is our potential to become a true, virtual networked organization, where every faculty member and every student on our campus will have an iLinc account, allowing them to participate in, set-up and manage their own sessions, be they conversations, conferences, collaborations, or classrooms. It is beyond the scope of this article to provide detailed training on the use of iLinc (so please visit the FDC), but it may be helpful to acquaint the reader with some of the useful pedagogical features of these tools.

iLinc supports multipoint video and recording, enabling participants to simultaneously see each other in a more dynamic way, and the session to be recorded while you are delivering your presentations or your students are engaged in collaborative activity. Quizzes can be administered during the session, as well as tailored Q&A, in the same way that clickers are used in the classroom. A chat box is available, facilitating text conversation between all or selected participants, and which can be blocked partially, or wholly by the instructor if preferred. Application sharing allows all or a portion of the desktop, regardless of which applications are in that region, as well as specific application(s) and web browsers, to be shared. Desktops can be split and glimpsed. The latter allows an instructor to monitor what a student may be doing remotely, when it is indicated that they are running other applications on their computer, or if they need help with a specific task or problem. Breakout groups can be organized and controlled, sending unique content to each group, or generating content for each group. Sessions can be scheduled at defined times, or they can be left open, providing a virtual collaborative space for students and instructor. Course content can be made available when in the session or through an email link sent to the participants.

The iLinc application itself downloads as a temporary client on the user's computer. A player and an editor of iLinc recordings remain available on the user's machine. iLinc is compatible with all operating systems: Windows XP/Vista, Mac OSX and Linux. It is not based on Java or Flash, and it supports both teleconferencing and VoIP.

iLinc has also a patented green meter technology, promoting the use of their technology to hold classes, meetings and remote experiment sessions over the Internet instead of traveling by automobile (or in some cases by airplane). Using the IP addresses of session participants, iLinc's technology estimates the CO_2 emissions saved by holding the session online. iLinc donates $100 toward renewable energy sources and carbon reduction programs for every business or institution that saves 1 million pounds of CO_2 or more by using iLinc's products.

Remote-Enabling Instrumentation

As a graduate student at UCLA in the 1980s, I could routinely remotely access, using a dial-up connection a computer controlling an X-ray diffractometer, an essential piece of instrumentation with which to conduct my dissertation research in protein crystallography. At the W.M. Keck Foundation Center for Molecular Structure (CMolS), a system-wide core facility here at Cal State Fullerton for the California State University Program for Education and Research in Biotechnology, our instruments were remotely-enabled in 1997, using commercial-off-the-shelf products in MS-DOS, six months before the Department of Energy collaboratories went online. Although it would be a few more years before these remote connections allowing control of instruments became robust graphical user interfaces, they provided research scientists, faculty and students alike, with the ability to conduct sophisticated research experiments from remote locations, using end-to-end cyber-infrastructure and the Internet. Remote data collection and observation is now routine in many areas of science, as is the use of high precision robotics and automation for handling of samples.

In 2005, CMolS, along with four similar core facilities located at predominantly undergraduate institutions, formed the nationwide STaRBURSTT-CDC[a], an e-consortium serving more than 150 PUIs and community colleges in diffraction science. In 2007, Cal State Fullerton, along with Cal State Long Beach, Cal Poly Pomona, Cal State Stanislaus, Fresno State, Harvey Mudd College, and Newport Harbor High School, established the CAL-PRISSM e-consortium. Using the iLinc interface, the *Partnership for Remote Instruments to Study the Structure of Matter* is providing access to instruments for remote experiments involving X-ray diffraction, inductively coupled plasma mass spectrometry, scanning electron microscopy, atomic force microscopy, confocal microscopy, nuclear magnetic resonance and electron paramagnetic resonance. Of even greater interest and significance, these instruments are being made accessible to secondary science classrooms to provide high school students and teachers with real-time data collection and analysis, as well as online simulations and communication with scientists.

Cyberinfrastructure Enables SAVI Learning

Students today are often mesmerized and overwhelmed by electronic media, and they fail to realize that to learn, one needs to be SAVI: Somatic (learning by physical activity); Auditory (learning by talking and interaction); Visual (learning by watching and listening); Intellectual (learning by reflecting, thinking, analyzing). Everyone has different learning modes or strengths, usually falling into one of four combinations: Connector (AV); Analyzer (VI); Applier (IS); Innovator (SA). Online instruction tends to cater to Analyzers (VI), and professors at Texas Tech University found that stronger students, those who have good general-comprehension skills, benefit more from talking an online course than students with less ability [18]. Cyberinfrastructure can be extremely effective at playing to the diversity of learning modes and strengths of students, while at the same time broadening their ability to learn by incorporating other modes: observing, analyzing, doing, talking (even IM).

History shows us that about every 20 years since the Industrial Revolution, groups of technologies have had major impacts on economic and social life, and enabling information technologies are no exception. Wealth of information, however, doesn't necessarily yield wisdom. Computers alone will not revitalize higher education because, with few exceptions (such as online traffic school), they cannot be good substitutes for instructors. Computers can be isolating. They tend to keep people physically passive, to appeal to one learning style, and to be media-based rather than experience-based. Effective use of educational technology realizes that learning is not simply about absorbing information. It is about creating meaning, value and actionable knowledge by the learner. Learning is not individualistic; it is enhanced by collaboration and interaction. Thus,

[a] Science Teaching and Research bring Undergraduate Research Strengths Through Technology – CyberDiffraction Consortium

effective use of cyberinfrastructure in higher education involves a) collaboration, b) exploration and experiment, c) delivering an option-rich environment, d) providing activity-based experiences, e) posing problems to solve rather than simply delivering a know-it-all repository of information, f) instructional design based on preparation, presentation, practice and performance.

Learning is best when it is *SAVI*, and cyberinfrastructure can facilitate *SAVI* learning. Knowing how to effectively incorporate these principles into instructional design will help our entire faculty to create effective blended learning environments, to do more, and to do it better, in this brave new cyber-enabled world of higher education.

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