Digital Infrastructures, Higher Education and the Net-Generation of Students

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Abstract

Students currently in higher education in the industrialised world have unprecedented access to web-based technologies and tools, and are likely to have engaged with online activities throughout their educational experiences. More widely, there is increasing pressure on universities to provide flexible learning environments and access to resources. This is keenly felt in the computer laboratory, where once dedicated, stand-alone machines provided software packages for students to work on during timetabled sessions. In recognising the move away from such patterns, Macquarie University is developing software and infrastructure to enable distributed access at any time to students, thus making a conceptual and physical shift from so-called 'Local Area Networking' to 'Wide Area Networking' and enabling greater freedom of access. The initiative is from within the Division of Economics and Financial Studies (EFS), but is applicable to students of any discipline in any university. This paper describes the development and discusses some of the implications for learning and teaching.

Keywords: Engagement, Remote access, Distributed learning

1. The changing use of educational technology

Technology has not just changed the tools we use in daily life – it is changing social habits, behavioural norms and expectations – (Oblinger, 2006, p.5)

In the quote above, Oblinger refers to changes in the expectations of students born after 1990; those who have come to be known as the 'net generation', 'millennials of the net generation', 'neo-millennials' and so on. These students are familiar with and rely on the Internet; they are 'net savvy' and "comfortable and confident in online environments" (Lorenzo, Oblinger & Dziuban., 2006, p.2). In these environments they expect to be able intuitively to operate the interface or software tool in order to achieve their particular goal, or to explore the digital environment. Moreover, these students are used to a certain immediacy of access to information, where and when they want it, placing new demands on IT services and professionals within higher education institutions. Dede (2005, 2006) anticipates a 'location and physical infrastructure' dimension to neomillennial learning, suggesting that resources such as computer labs that accomplish specific activities in specific locations will in the future be distributed over space and time, and that the notion of 'place' will be dispersed to "fragmented, fluctuating habitats" (Dede, 2006, p.16). He describes these as 'multi-purpose habitats' rather than specialised locations. Within these distributed and non-specialised locations, it is expected that 'Web 2.0' (O'Reilly, 2006) online applications will be easily shared and will enable interaction with software, people or information, wherever one has access to the Internet. The technological and social changes described above mean that higher education institutions have political and economic choices to make about how they respond to these new challenges, opportunities and dilemmas, as suggested by Wager (2005):

Matching institutional practice with technical features is another decision point; most likely there will be a mismatch. Should institutional practice match the capabilities of the IT system, or should custom IT solutions be developed to meet the service needs? With the former, changing the institutional culture is at best difficult, and at worst divisive. With the *latter, the institution loses the leverage of maximizing future system growth and enhancements unless corresponding modifications are made to custom software modifications. (Wager, 2005, p.18)*

There is evidence (Krause, Hartley, James & McInnis, 2005, pp.41-46) that the majority of Australian students (90%) have adequate access to computers and that there is an “almost universal” use of online materials, “with 95 percent of first years saying they used web-based learning and course materials” (Krause, 2005, p.5). Coates (2006a) expresses some concern that these students are being, “treated as unproblematic ‘users’ rather than ‘learners’ engaged in the complexities of constructing their knowledge … [and that] we do not know much about how undergraduate students engage online with activities and conditions likely to promote learning and development” (Coates, 2006a, p.2). We do know, however, that Australian university students spend less time in private study than they did a decade ago, with an average of 16 hours class contact and 11 hours private study (Krause, 2005, p.5). The corollary must therefore be that if there is anything we can do to make access to laboratory-type work easier, more seamless for the student, and afford the students an online environment conducive to their learning, then we may be enabling better engagement with the learning required in the limited time that is available.

The technology itself has changed; what were once ‘stand-alone’ computers, each with their dedicated software, became networked into a ‘local area’ (or LANs) then with the development of other applications and wireless technologies have become ‘wide area networks’ (or WANs). The opportunities afforded by such technology can be capitalised on so long as the human interface has integrity and ease of use. This move toward the WAN is more indicative of the humane and reflexive use of technology called for by Norman (1999) when he suggested that, at its best, computing technology can afford:

New modes of interaction, of learning … Products in the world of information technology have suffered far too long under the existing technology-centred designs. It is time for a change, time for a human-centred design philosophy. People are not machines, they have very different requirements (Norman, 1999, p.261).

In this case the technology has enabled a new pedagogy, one much more appropriate to today’s student and that enables access to study materials and tools whenever and wherever students wish. This leads to a recommendation, that the technology should meet the needs of the user rather than the user having to conform to the needs of the technology. In turn, another recommendation might be that the technology should be as unobtrusive as possible; and another, that the modes of learning be fully understood and explored to maximise the benefits afforded by the new remote-access opportunity. This may of course have implications for the design of curricula and teaching methods.

2. Remote access in the context of Macquarie University

At Macquarie University, there are about 1 650 student computers spread across 60 student computing laboratories of various sizes. These support the computing requirements for a total enrolment exceeding 31 000 students, of whom just over 11 000 are postgraduates and approximately one-third are international students. These computing laboratories are used both for classes and individual student study. Most are dedicated resources in so far as they contain the relevant software applications required for students to complete their coursework. The University maintains a wireless network that covers a large portion of the outdoor area surrounding academic buildings, and provides basic Internet access for students who bring their own laptops onto the campus. A significant proportion of the dedicated student computing laboratories are managed by the various academic Divisions within the University.

The Division of Economic and Financial Studies (EFS) is one of the largest academic faculties within the University. It has an enrolment of approximately 13 000 students, including about 3 000 postgraduates. It has a higher ratio of international students than the University as a whole. The Division provides around 450 student PCs, spread over ten student computing laboratories of various sizes. These are all dedicated computing laboratories containing the software applications required for EFS students, and are used jointly for classes and individual study.

As software licensing arrangements for many of the required applications often restrict access to within the University environment, typically students have been required to travel to campus to undertake the computing requirements of their coursework. At popular times this may result in them having to compete for the resources. A further limitation for students is that large student numbers generally entail large class sizes, and several EFS Units have enrolments in excess of 1 000 students. Hence the Division is keen to embrace technology to improve its students’ learning experience and engagement.

As a consequence of the above, some educational objectives and imperatives are starting to emerge. Remote access to software applications and data that are currently available only on campus and from specialised, discipline-specific computer laboratories would make the access to material more efficient. Further, this accessibility should encourage learners to engage with the material at a time and location they perceive to be most conducive to learning and their material needs at any given time and space. The objective is to utilise web browsers to provide this accessibility with the imperative that students would be able to access whatever software program they wish, and indeed have multiple applications open in different windows if so desired. The EFS Virtual Lab therefore has the aim of enabling students to access computer laboratory applications on any computing device, from any location, at any time. Whilst this initiative and innovation is being developed in EFS and at Macquarie University, the software could be used by students of any discipline within the University; and potentially by any university seeking to distribute and enable remote access to computer-based applications.

3. An emerging solution and product

Given the contexts described above, a Product Design Specification (PDS) for the EFS Virtual Lab was developed. Consultations with students suggested that they would welcome the external availability of previously in-University-only software applications, but that the specification should primarily focus on the benefits for students. Such a user-centred approach is not surprising and the specifications we derived included the ability to:

(1) access all EFS student software applications, personal and shared data from any location;

(2) provide access at any time to all software required for their coursework;

(3) obviate the need to travel to campus to undertake individual study;

(4) offer on-campus access to software from any (rather than a dedicated) computing laboratory;

(5) enable units of study, regardless of their national or international location of delivery, to be supported by and with the same access to the required software.

When taking the developer and University perspectives into account, there were a number of additional primary technical performance and security specifications:

(1) accessible from any computing device that supports a web browser and a Java Run Time Plug-in (such as laptop, PDA and so on);

(2) printing and file saving can be performed locally;

(3) performance times comparable to those on campus;

(4) a scalable system for a potentially large number of users;

(5) encrypted information transfer; and

(6) password and authentication protected.

To meet these specifications and to extend computer laboratories beyond the confines of the University, a number of technology components have been integrated. Software drives the integration of server-based applications, web interfacing and the sessional information seen by the student. Each student sees only his or her session, which is managed transparently and independently by a server. To gain access the student connects to the Virtual Lab website, part of the University's web pages. This opens a secure 128bit encrypted connection and once authenticated a Java applet runs and presents a menu of applications available to the student. This happens at the beginning of each session and, unlike ActiveX controls, nothing is stored on the student's computer. Essentially this means that any computer terminal anywhere in the world can be used to access the menu of applications made available by EFS. To conform as closely as possible to the design specification, the requirements made at the user end of the system have been kept to a minimum. This implies avoiding the need for any software or configurations required specifically in order for the user to access the Virtual Lab and thereafter to access the applications they want. The Virtual Lab architecture is represented in Figure 1.

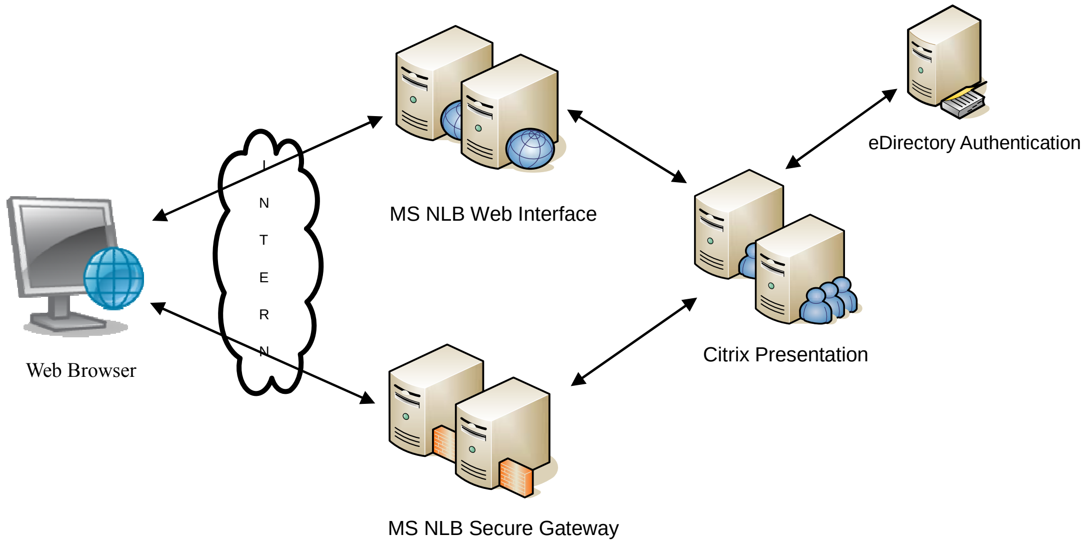

Figure 1. Schematic representation of the EFS Virtual Lab

At the time of development, a Citrix solution was selected. Citrix enables users (in this case students) to access applications hosted on another computer, that is, two physical servers each running Citrix Web Interface and Citrix Secure Gateway. Behind these servers is a ‘Citrix Farm’, currently containing two Citrix Presentation Servers, which are incrementally scalable to cater for any increase in demand. This means that several users can access the same application at the same time. The only requirement is that the users have a web browser (such as Internet Explorer, Netscape, Mozilla Firefox and so on) that supports a JAVA Run Time Plug-in at their end (that is, on their computers). In effect the students would be accessing the application from the server but it would not be downloaded onto their computer, even though the application would appear to be behaving just as though it were resident on their computer. There is a downside, however, in that choosing local printers and file locations is not clearly identified – so some familiarity is required by the user – but this problem will be addressed in subsequent versions. All of the processing is performed at the server end. The server hardware is duplicated and clustered for load-balancing and redundancy thus optimising availability and performance and ensuring the applications will still be available in everything but the worst-case scenario. When the student starts a session, the screen images are generated by a VMware ESX Server and are delivered by a Citrix Presentation Server in an encrypted state to the JAVA Plug-in on the student’s machine. Java in turn presents the images to the student through a web browser as described.

Of course, security is an issue with any distributed computing practices. In the case described here, authentication and thereafter access to networked directories is provided through Novell eDirectory. Students use a web browser to establish a connection to the Web Interface Server via the specified URL (Uniform Resource Locator). As part of this process a secure SSL/TLS (Secure Sockets Layer/Transport Layer Security – cryptographic protocols) connection is established, and all information transferred from this point is encrypted. This preserves the security of the student’s login details. Thereafter, the student sees a login page, into which they enter their username and password. When authentication is established, information flow is reversed and the Web Interface Server populates the web page with the list of resources. In this case, it is an icon for the EFS Virtual Lab. Students click on the icon, and a Java pop-up box will appear on the screen (if the Java Plug-in is not installed, students will be prompted to download it). From this point, all information flowing between the students’ browsers and the Presentation Server is directed via the Secure Gateway. After a few seconds the Java pop-up box will disappear, and students will be delivered a virtual version of the EFS Student Laboratory, complete with applications, just as if they were on campus.

4. Evaluation

The project has two principle evaluation needs – an evaluation of the design solution from a pragmatic (how does it work?) perspective as well as a user-needs and characteristics perspective (how are the students using it and to what effect?). At the time of setting out the Product Design Specification (PDS), an evaluation matrix (Appendix 1) was developed that cross-referenced evaluation-type questions against data collection methods (see Georgia Technical College, 2007). This will inform the impending evaluation and has helped to focus design decisions throughout the development of the product. At the time of writing the distributed system has undergone technical evaluation, and we are at the very early stages of user evaluation.

To provide a comprehensive and realistic assessment of the success of this project, several evaluation methods have been considered. These include, amongst other things, expert review, implementation/user logs and system tests aimed at measuring how closely the technical requirements are met; together with observations, user interviews and user questionnaires aimed at measuring how closely student expectations are met.

User evaluation will be based on the perceived benefits to students emanating from the PDS. These are classified into four broad groups: Availability, Security, Performance and Design; and evaluation questions were formulated under each of these headings. Several relevant data collection methods were considered and, utilising the Georgia Technical College (2007) approach, an appropriate set of data collection criteria was established (shown in Appendix 1).

Availability is measured through technical evaluation via standards, testing and performance logs. These indicate whether the deployment meets the flexibility requirements of the PDS. Moreover, user confirmation provides feedback on how students value this. Similarly, performance is technically evaluated via standards, expert review, testing and anecdotal records. Measuring student expectations is, however, probably the most critical factor, as student perception of performance has an important influence on their perceived benefits of the whole product (Jordan, 2000).

Security tests and expert review reveal whether the installation has been configured to appropriate security standards, and that data encryption has been correctly deployed. Also, student feedback is sought to confirm that they are required to enter their username and password prior to gaining access, and that files copied between local and network folders are readable after transmission.

Design functionality includes characteristics such as intuitiveness, ease of navigation, consistent ‘look and feel’. Expert review confirms whether the technology has been optimally configured in this respect. Already, some shortcomings have been described with respect to intuitiveness related to local printing and saving functions, and this has been reinforced by anecdotal evidence. These are expected to subside as students gain familiarity with the application. Student input will be sought to determine the degree of difficulty faced, and to offer ideas that will assist students to accommodate this.

It has been assumed that associated benefits to students, such as increased flexibility and personal organisation, will enhance their learning experience, as suggested by several authors (such as Coates, 2006a, 2006b; Krause, 2005). As the application matures, students will be invited to assess and evaluate the affordances (Norman, 1998) offered by the EFS Virtual Lab. Several academics have indicated that their students would be keen to take part in user evaluations enabling a rich evaluative framework relative to the matrix in Appendix 1, the outcomes of which will be reported in a later paper.

Herrington, Reeves and Oliver (2006) have discussed the benefits of technology in freeing the (distance) learner from the constraints of time and place and thereafter have attempted to describe synergies between the learner, the task and the technology using a bipolar model similar to that in Figure 2.

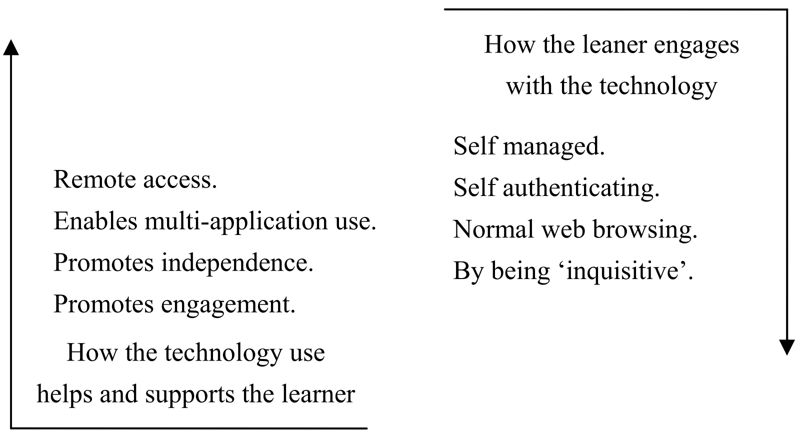

Figure 2. Synergies between Technology and Learner Engagement (After Herrington et al., 2006)

Figure 2 is constructed by balancing the perceived benefits (by the student of the technology) against the ways in which the students support and uphold the use of the technology. Initial discussions with the students trialling the system have revealed that they appreciated the ability to access their (multi) applications remotely and that this encouraged them to engage in more independent activity than they might normally otherwise commit to. It was the ability to explore the system and to work as and when they chose that most encouraged this independence. These perceptions are, however, based on some other precursors, namely the ability to do certain things such as open files, authenticate oneself as a user, and to generally drive the system to some personal self-satisfaction.

Results from this project have demonstrated that the concept of the EFS Virtual Lab, as specified in the PDS described earlier in this paper, is achievable through current technology, albeit with a slight limitation. Nonetheless, further research is required from a user perspective. The Evaluation Matrix approach was a useful tool in the evaluation process. We intend to make further use of it as we attempt to define the significance of the Virtual Lab to our students’ learning experience, and measure the uptake rate.

Of course, one of the issues related to distributed learning is the downturn in opportunities for face-to-face working and collaboration. The student engagement literature places a positive emphasis on opportunities for collaboration and time spent on campus and within a community of learners. At first glance, the innovation described here could be seen as counter-productive in that it removes the need for students to be located together at the same time to undertake learning tasks. To overcome this problem and to reconceptualise the nature of learning (and learning support) in this environment, it is intended that some form of social-networking tool will be provided alongside and from within the EFS distributed website. This should provide the potential to encourage a virtual community of enquiry (Parsel & Duke-Young, 2007). Such a community of enquiry is ideally supported through discussion boards where students interact with each other for the purpose of learning collaboratively, and from the build-up of knowledge within the community. In short, the community of enquiry becomes a self-supporting network as students share practices, successes and failures with their peers. This affords more self-regulatory feedback in the hope that students become less reliant on the teacher for feedback and control.

5. Conclusion

We have described a product to our knowledge unique in higher education, which can be used to deliver software applications required by students to do their course-work, anywhere in the world at any time with minimal user system requirements. Clearly this affords a number of opportunities for the various users, by no means limited to students of EFS or Macquarie University. The University is able to free up and increase access to space traditionally dedicated to stand-alone and LAN computer terminals, which are often tied to a particular discipline area. Many universities, including Macquarie, make extensive use of LAN-based technology to control and manage student access to the various computing-laboratory resources across campus, as this is the most effective technology for small, homogeneous, well-defined geographic areas. This is a widely adopted practice in teaching institutions as it provides greater opportunities for standardisation and access control. By implication, this necessitates students having direct physical access to computing laboratories. In contrast and in using the solution described here, a WAN technology is designed to cope with heterogeneous access over broad geographical areas. Information providers have little control over configuration of the equipment through which the information is provided. Hence, they are primarily concerned with the integrity of information flow rather than the associated equipment and computing hardware. This is particularly evident with the Internet, which is the most overt example of a WAN. It is in this paradigm that the EFS Virtual Lab resides, and therefore significantly differentiates it from the standard student computing-lab methodology.

The innovation described here enables access to the software used by EFS students from anywhere within the University, either from other University computing labs or over the wireless network. At a time of increased pressure and demand on such resources, this becomes particularly attractive and useful for the University's facility management. It also enables flexibility and accessibility for the students and this is seen as beneficial, given the rising need for students to accommodate other elements into their student life such as part-time working or at-a-distance education. Here then, we have a significant conceptual difference from a 'lock it down' LAN viewpoint to an 'open it up' WAN perspective. This reflects how an institution's choice of network technology can influence its IT delivery, and hence affect the way in which students interact and engage with IT as part of their learning environment. This approach could be applied across any institution and to any students (and staff) wishing to access software remote from a campus. Of course, the technology is only part of the system of implementation. Elsewhere we need to make well-informed decisions about how to introduce such changes to working practice and to assess the impacts they have on associated pedagogies.

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Appendix 1. Evaluation Matrix

PERCEIVED BENEFITS FOR STUDENTS		DATA COLLECTION METHODS						
		Expert Review	Implementation/User Logs	Tests	Anecdotal Records	Observations	User Interviews	User Questionnaires
	Availability:							
1.	Can be accessed from any computing device that will support a web browser, and a Java run time plug-in	x				x		
2.	Students can remotely access all EFS student software applications, and personal and shared data, from any location (including Internet Cafes).		x	x		x		x
3.	Printing and file saving can be performed locally.		x	x		x		x
4.	Potentially provides students with 24x7 access to all software applications required for their coursework.		x	x		x		x
5.	Students are not required to travel to the campus in order to undertake individual study.						x	x
6.	Potentially enables students to work from any Student Computing Laboratory on campus. *(This will enable the University to offer these resources to students in a more efficient and flexible manner.)*	x	x	x				x
7.	Units can be packaged and delivered either locally or internationally in exactly the same format, as students (either local or international) will have the same access to Student Computing Lab resources. (Benefits to distance and international students.)	x	x	x		x		
	Security:							
8.	All data transfer is encrypted.	x		x				
9.	Students must successfully authenticate themselves before gaining access.		x	x				x
	Performance:							
10.	Performance times are comparable to those of existing EFS Lab PCs.	x		x	x	x	x	x
11.	The system is scalable, so that it can be expanded readily to support the needs of a large numbers of users.	x		x				
	Design:							
12.	User experience must be intuitive				x	x	x	x
13.	Must be consistent with current Computing Lab "Look & Feel" (branding)	x					x	x
14.	Ease of navigation				x	x	x	x
	Associated Benefits:							
15.	Flexibility				x		x	x
16.	Personal Organisation				x		x	x
17.	Comprehensive Functionality				x	x	x	x