

DESIGN AND IMPLEMENTATION OF A WEB-BASED LEARNING ENVIRONMENT Lessons Learned

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This article presents sets of observations and recommendations for Web-based distance learning, based on formative and summative performance and opinion data collected from participants involved in the design, development, and utilization of Wired Class, a Web-based learning environment that was developed to teach mathematics to Egyptian secondary school students. The discussion focuses on issues related to the nature of (1) Web-based learning materials, (2) the spectrum of learning/teaching interactions, (3) the Web as a learning environment, and (4) costs associated with delivering Web-based instruction. Examples are used to illustrate the basis for recommendations that evolved from the work on which this article is based.

Web-based instruction is a relatively new educational technology with many Web-based courses developed by people skilled in Web authoring but who “are not necessarily knowledgeable about educational concepts” (Janicki & Liegle, 2001). Powell claims that “despite the established base of online courses, online course design and facilitation is still uncharted territory for many college and university faculty” (2001, p. 44). Although much has been published about creating effective online learning, much of the literature does “not pro-

vide a comprehensive and practical guide to the challenges faculty encounter when designing complex Web modules” (Weston & Barker, 2001, p. 15). Online learning environments should meet many instructional, structural, and technical principles of design and development to be more than information dumping, and to avoid eyestrain from endless text screens, confusing navigation, and long download times (Spitzer, 2001). It is essential for responsible administrators to understand if their Web-based distance learning programs

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are meeting their design objectives or are merely alternative learning materials dumping grounds.

Many studies (e.g., Clark, 1994; Lockee, Burton, & Cross, 1999; Thorpe, 1998) have pointed out that that different levels of evaluation should be used to evaluate distance education programs. Clark (1994), for example, stated that two levels of evaluation that always provide useful feedback are measures of participant reactions, and the achievement of program objectives. Consequently, the “lessons learned” described in this paper are based on formative and summative student performance measures as well as student, instructor, designer, and “expert” opinion data collected during the 12 months of design, development, and utilization of *Wired Class*, a Web-based learning environment that was developed to teach mathematics to Egyptian secondary school students (Sadik, 2002). Constructivist epistemology provided the basis for the various instructional components and the related problem-centered and interactive activities used in *Wired Class*.

In this paper, “lessons learned” are discussed in terms of the following topics:

- providing a rich learning environment;
- understanding the spectrum of interactions;
- developing the presentation environment; and
- considering the cost benefits.

Each of these is discussed in terms of issues germane to specific characteristics of the topic.

PROVIDING A RICH LEARNING ENVIRONMENT

Web-based instruction is an instructional delivery mode that has evolved from traditional instructional delivery environments; hence, many online materials have been derived from traditional instructional material, typically textbooks. Unfortunately, converting

textbooks to Web pages can result in digital versions of textbooks that provide no incremental benefit for learners. In this project, considerable time was spent converting and redesigning original textbook content to produce a rich online learning experience. Special efforts were made in terms of content design, the activities necessary to support and reinforce student learning, developing ancillary learning materials and resources, and utilizing Web resources. This section describes these efforts and some of the implications of each.

Content Design

In many (if not most) programs of instruction, course and lesson objectives are not always clearly presented to students, either initially or throughout the progress of a course. Course objectives are essential because they help instructors plan the structure of a course and develop learning activities and assessment methodologies (Berge, Collins, & Dougherty, 2000). The online learning materials developed in this project were derived from textbooks in which learning objectives were not stressed or made obvious to learners. This deficiency in the online materials was addressed by presenting learning objectives at the beginning of each lesson together with basic/new concepts and definitions to support those objectives. This was done continuously throughout the instruction to reinforce the learning of new concepts and to help students acquire and construct new mathematics meanings and principles.

Mathematical content is difficult for many students, particularly for those studying independently at a distance. Online content can provide learners with multiple forms of media (e.g., hypertext links, graphics, animation, real-time audio and video, and other hypermedia objects such as Java applets and Macromedia Flash presentations) to involve them in active learning activities (Weston & Barker, 2001). Other online tools/effects that can be used are links to Web sites with authentic contexts or sites that afford access to primary

source documents, and immediate automated assessment and feedback (Weston & Barker, 2001). Consistent with Harrison and Bergen (2000), *Wired Class* utilized such technologies to provide students with complete and up-to-date views of the subject matter, including main concepts, links to Web resources, examples, exercises, reminders, and so forth. The use of a variety of well-selected, real-life examples helped students focus on new concepts and understand difficult issues by applying them in new ways, especially when alone and with less access to instructor assistance than is common in face-to-face learning environments. Accordingly, more real-life examples were provided so that students could practice new concepts and skills in an independent and comprehensible manner.

Learning Support Activities

Web-based learning platforms provide an ideal environment in which to implement the principles of constructivist learning (Smith-Gratto, 2000); *Wired Class* was implemented on that basis. Constructivists assert that students construct their own learning in meaningful ways when they participate in individual and social activities, encounter and solve problems, interact with others, exchange information, and evaluate their understanding. Accordingly, different kinds of resource tools such as graphing calculators and situational problem solving exploration methodologies were provided to assist students achieve high-order learning objectives.

Although the mathematics content of *Wired Class* was accurate, addressed the learning objectives, and was thought to be interesting, rewriting the content for the Web with constructivist epistemology in mind required the development of strategies to encourage frequent and meaningful online student interactions in debates, problem solving, and general discussion. Students were involved individually in many real-life problem-solving activities through self-tests, exercises, and discussions. Through social interaction, facili-

tated by e-mail and discussion boards, students could learn others' points of view and assess their own understanding. However, it was felt that it was imperative for instructors to take an active role in helping students construct meaning and correct misunderstandings, and that discussions (via discussion boards) take place continuously throughout the lessons, and not be "add-ons" at the end of lessons.

Learning Materials and Resources

In *Wired Class*, course content was organized in a "conventional" yet flexible way. Each lesson was segmented into the lesson, further examples, self-tests, and exercises. Every module was segmented into smaller, labeled and interlinked submodules, each representing one concept, skill, or problem. This design was useful for students and instructors because the meaningful labels of the submodules provided easy to identify reference points that facilitated communication among instructors and students. The relatively fine submodule design also facilitated diagnostic action if students had problems and/or remediation was required.

One of the advantages of the World Wide Web is that ancillary technologies can provide media rich browser-based screens of information. *Wired Class* lesson material deliberately did not contain complex multimedia objects because most students accessed the Internet via slow phone line connections using hardware that was not state of the art. Additionally, and from an instructional development standpoint, it is expensive and time consuming to develop audio and video objects, most of which may not really be useful for subject matter that is heavily based on text, symbols, and graphs. Small and relatively low resolution still and animated GIF images were used to display figures, graphs, and mathematical formulae; interactive Java applets were used to illustrate abstract mathematical concepts and capture student interest. Although there are many other ways to generate and display mathematical formulae in HTML pages (e.g.,

HTML maths tags, Java applets and add-ins), GIFs were found to be more cost-effective and better able to represent attractive and accurate formulae. These other approaches can provide inaccurate results, require a long time for downloading, or require additional software (plug-ins) to be added to the Web browser. The only drawback to using images was the large amount of disk space they took up in the Web server.

Web Resources

Web-based education can provide learners with limitless information resources, but despite ease of access and probably because of the scope of the resources, expecting students to find and integrate them in a meaningful way may not be realistic. Instructional designers should pay attention to developing subject-specific directories or topic hot lists that are accessible and appropriate to students' academic levels. Lilla and Hipps (1999) highlighted the importance of a combination of subject-specific directories and search engines that they called "hybrids." The importance of hybrids is that they collect and categorize Websites in a logical or subject-based structure so that the user avoids the false hits that can occur with search engines. The advantage of these hybrids is that they allow students to do all their information gathering from a single desktop connected to millions of computers all over the world (Green, 1997).

In a distance education context, Birmingham, Drabenstott, Frost, Warner, and Willis (2000) reported that the advantages of hybrids or "digital archives" are that:

- They reduce geographic, organizational, and time barriers of distance.
- They enhance collaborative and group-based activities.
- They provide access to collections of information in multimedia formats that are not available to off-campus students.

- They allow users to personalize or customize information access and representation.
- They provide information at any time and in any place.

In *Wired Class*, students were provided with an archive of preselected Web links and with access to powerful search engines (e.g., Google, Yahoo, AltaVista, etc.) to search for course-related information. Consistent with the literature cited above, students reported that they did not benefit very much from these tools or even from following preselected Web links. Feedback from instructors revealed that many of the resources were above the ability level of learners and did not seem to cover topics comprehensively. Instructors recommended that search engines and links be carefully selected with consideration of the subject matter (e.g., mathematics) as well as students' levels and needs. Although this is a time-consuming instructional design activity, it is now clear that it is important for curriculum designers to find and carefully select prescribed curriculum-specific Web resources. This was borne out by students' experiences where they reported that they found such links more appropriate and useful than general search engines. This result is also in line with results reported in the 10th Gvu public survey (1999) approved by the World Wide Web Consortium which showed that the majority of users prefer and use links provided by other Web sites rather than using search engines to seek information themselves.

A no less important observation is that it is essential to verify the legitimacy and provide continued support of links in archives. In *Wired Class*, students reported that they found error messages instead of the resources to which they had been directed. According to Gvu's 7th (1997) and 9th (1999) WWW User Surveys, in 1997 about 50% of Internet users reported broken links as their main problem in navigating the Web, and by 1999 this problem had become even worse. The only solution to this problem is for links to be regularly

checked, and for there to be feedback mechanisms for students to report or comment on broken or difficult-to-follow links.

UNDERSTANDING THE SPECTRUM OF INTERACTIONS

A challenge of distance learning is overcoming the geographical separation of instructors from learners, and learners from other learners. Students in distance-delivered courses are expected to carry out a great deal of learning on their own (Baynton, 1992). It is essential for instructors to know whether remote students working alone and online are able to construct their knowledge successfully or not (R. Garrison, 1990). Because there is evidence that in classrooms with higher levels of interaction students have higher levels of achievement and more positive attitudes toward learning (Ritchie & Newby, 1989), it is also essential to optimize the learner/learner and learner/instructor quality of interaction. Too often, attention is given to the content and the delivery features of communications technologies rather than to the human dialogue that must take place in the online learning environment (D. Garrison, 1989). Nevertheless, participants must still be provided with a variety of explicit and implicit participatory methodologies in order to avoid feelings of isolation and to constructively participate in the online learning environment. The following section addresses the quality and effect of participants' interactions in *Wired Class*.

E-mail

Students did not find e-mail to be a useful and easy method of interaction with classmates. A reason, as recounted by one student, was that classmates did not regularly access and check their e-mails nor quickly respond to others' messages. Feedback from a student who did not think that using e-mail was a good method of student-student interaction indicated that, "To contact my classmates I have to

use the e-mail, but only a few students get into e-mail and use it. Contacting them is very difficult."

This experience suggested the need for a more reliable communication medium to encourage and facilitate interaction among online students. An asynchronous interaction tool, *Quick Messenger*, was developed to address this need, allowing students to send and receive messages using instant messaging (IM) tools. Students could check to see who was online and send quick messages to anyone currently connected to *Wired Class*. When the other party received the message, an alert to that affect displayed on the receiver's screen, allowing the message receiver to read it and instantly respond without having to close the main window or move to a new page.

Discussion Boards

In *Wired Class*, although discussion board participation was essential and tutors sent many reminder messages to students to participate, the average number of postings was very low (one message per student per two weeks), and many students "lurked" and posted fewer than three messages for 12 discussion topics. Students commented that they did not participate because (1) they could not post "correct answers" that would add meaningful value to discussions, (2) they had nothing to say, or (3) they did not consider discussions to be as important as conventional tasks. Other interesting characteristics of discussion communications were:

- The majority of students accessed discussion boards only in the last few minutes of a lesson deadline. This may have been because the discussion questions came at the end of each lesson.
- Because discussion questions varied in complexity, in discussions that addressed more debatable questions, students were motivated enough to engage actively in critical thinking processes and paid more attention to interaction

with peers. Topics that required low cognitive effort did not help students use higher order thinking, interact with others, or learn from others' experience.

- Participation rates increased as the term went on. Flottemesch (2000) reported that students rarely interact via discussion boards because of a lack of opportunity to develop peer relations and/or because of intimidation about using new technology. After 4 or 5 weeks of studying in *Wired Class*, students who had not previously participated in discussions began to participate actively and become familiar with the new style of technology-based constructivist learning.
- The more the instructor participated, the more messages students posted. This is consistent with Harris (1999) who reported that the role of the instructor in discussion is as important as the role of the "chair of a conference." He argued that the instructor's role is essential to open and close discussions, to encourage students to participate and interact, to keep discussions on track, and to assess learning. Jonassen, Myers, and McKillop (1996) claimed that instructor-student interaction "exemplifies the constructivist design model" of online education, but the instructor's contributions should be only 9-15% of the message volume. Trentin called the instructor's modest participation the "initial approach" necessary to break "the ice between the students and those responsible for leading and assisting them throughout the course" (Trentin, 2000, p. 19). According to Trentin, the outcome of using this approach is that distance learners' sense of isolation is reduced and this helps to enrich and foster discussion. These findings suggest that online instructors should pay close attention to strategies that foster participation and build a sense of community. This can be achieved by directing ques-

tions to students, asking them to suggest new learning materials or Web links, or posting alternative points of view on discussion boards.

- The quality of social and cognitive-related interactions in the discussion groups appeared to be very low. This was apparent in students' superficial responses, which tended to (1) repeat information from others' messages without additional explanation, (2) support/reject others' opinions without adding personal comments or providing clear evidence, (3) offer solutions without providing clear interpretation, (4) provide solutions directly depicted from the text, and not from external Web resources or self-experience, and (5) ask questions that were not directly related to the discussion topic.
- Content analysis of students' discussion board messages showed that when students were challenged by discussion questions, they did not resort to Web links and this did not allow them to find information to clarify the discussion problem or respond to the discussion question.
- Although learner-tutor interaction is one of the key features of Web-based distance education and is interrelated to both learner/learner and learner/content interaction, it was found that it is not a significant factor in determining students' academic success unless there is a sufficient quantity of relevant, motivating, and content-related messages passing between and among correspondents.

In summary, because interactive and cooperative learning is a function of students' interactivity levels and social skills (Fisher, 2000), and since the learning process is influenced by proficiency in information manipulation (Henri, 1991), little educational effectiveness can be gained from involving students in group discussions if they are unable to carry out in-depth processing of dis-

cussion problems, are not interested in group-based learning, or do not have the necessary skills and experience to participate in such activities.

Interaction with Course Content

For learning to occur, students must interact and process the content of the course themselves (Bower & Hilgard, 1981). The design and development of the content is very important, not only to facilitate learner-content interaction but also to direct and foster other types of Web-based interactions which are vital for the success of learning (Kanuka, 2000; Moore, 1989). According to Moore, learner-content interaction is important in obtaining intellectual information and constructing knowledge from the course material. This type of interaction takes place in a variety of ways and many strategies can be developed to help students obtain information from the material.

In *Wired Class*, the most important issue considered in designing the content was learner-content interaction. Students were able not only to read the content in short and visually attractive chunks, but also to explore, browse, and choose before reading throughout the lesson. Students were able to choose and link among chunks and to previous lessons or support materials, use interactive visuals (elements, graphics, animations, and tools), search the library catalog, seek more information in links provided with each lesson, assess their learning and receive auto-feedback, submit their work, and receive immediate feedback from instructors.

As a result, it was not surprising to find that students' perception of student-content interaction was a significant factor in predicting and explaining their academic success. Student performance measures indicated that learners who were satisfied with interaction with the structure and format of course content earned higher grades than those who were not.

DEVELOPING THE PRESENTATION ENVIRONMENT

Too often, classroom-based research studies in education are unable to state that one treatment is conclusively superior to another. Researchers explain their results by asserting that there may have been uncontrolled and immeasurable effects introduced by the learning environment. Online learning environments may have an advantage over classrooms as research laboratories since there are more factors that can be controlled in online instruction. The controllable or manageable characteristics of online instruction should be used to try to optimize the learning experience for students, whether for research purposes or for real learning. This section of the paper describes some of these.

User Experience and Training

One issue that can affect student learning in Web-based environments is students' previous computer experience. Whether students possess substantial or minimal previous computer experience, the learning environment must be selected or designed to reduce the effect of that experience on the learning that is to take place.

Wired Class was designed for students with minimal Internet experience, so it was not surprising that student performance measures failed to indicate significant relationships between previous Internet experience and satisfaction and perception of ease of use of *Wired Class*. This means that if the design and structure of the learning environment are friendly and usable, students' previous Internet experience and skills may be discountable, and students can learn via the learning environment without their background influencing their expectations or their learning. However, this does not mean there is no need to prepare students or enhance their experience and skills to use computers and the Internet.

According to student and instructor feedback, a Web learning environment such as *Wired Class* should be acceptable if:

- It is appropriate to students' experience level and does not require prior experience in using the Internet or Web-based learning.
- No obvious technical problems are present.
- Students are able to learn to use the system in a very short time.
- It provides a variety of tools for students to access information and contact instructors and classmates.
- Communication tools are easy to use.
- It provides tools for instructors/designers to edit and publish Web pages without having to learn HTML or principles of Web design.

On the other hand, Web learning environments may have deficiencies. Some *Wired Class* users suggested that the following kinds of issues bear attention:

- Most learning management systems are text based and require learners to have good spelling, vocabulary, grammar, and typing skills. This can affect the kinds of constructivist learning activities an instructional designer might employ. For example, asynchronous rather than synchronous activities may be preferred by students who wish to perfect constructed communications before transmitting them electronically to other learners or instructors. This is unlike chat rooms where spontaneity of responses is required for participation.
- Web-based learning environments require usually untrained learners (and instructors) to deal with hardware such as printers and modems. Users must also deal with the myriad software issues that inevitably arise from Web-based Internet connectivity issues such as plug-ins, viruses, spam, and so forth.
- There should be online help (preferably multimedia-enriched) to guide students through the learning environment, particularly at the beginning of instruction

when the interface is likely to be unfamiliar, whether or not it is user-friendly. There should also be online content- and context-related help to direct learners to Web-based learning resources.

- Users should have access to online manuals that are searchable and linkable from online help. The online documentation should be printable for offline viewing when Internet connections are not available, or for use as adjunct material when online instruction is taking place.

Website Navigability

Today, most Web-based instruction in education is delivered via learning management systems such as WebCT or Blackboard. Such commercial systems are typically optimized for online learners and take into account the kinds of issues described above. However, often and for a variety of reasons institutions or instructors are unable or prefer not to utilize commercial systems, but instead create their own customized Web-based online learning environments. Whether a vendor or home-built strategy is adopted, there are many issues beyond content design that the instructional designer must consider: ease of site navigation must be a central aspect of instructional Web sites. In *Wired Class*, the aim was to help learners to understand the structure of the site so that they could logically locate content, learning resources, and tools. Following are some of the practices that were employed in *Wired Class*:

- In Web-based instructional delivery environments, the starting page must serve as a crossroad or origin point to guide learners toward exploring, understanding, and navigating through the site. In *Wired Class*, the starting page provided an overview of the whole site, categorizing the major areas, providing a brief description of each, together with its links. Well-designed homepages

have been found to be essential for young and well-trained users who return to the homepage frequently to regain their orientation and to locate information (Meyer et al., 1997). Therefore, links in the homepage must be categorized and detailed, but with a moderate number of links to prevent learner confusion. These links should not take the learner too far from the starting page. At the same time, a homepage link should be available on each lesson page to take the learner back to a familiar place on the site.

- A number of navigation conventions were adopted in *Wired Class* to prevent learners from getting lost in the Web site. Rather than rely on either module presequencing or learner-controlled exploration, an index of links was provided. It was felt that the consistency of design as well as the ability for students to track their pathway in the site using pull-down menus, toolbars, and expanded/extracted menus would help them define their location and keep them visually oriented. Expanded/extracted Java Script menus were used to maintain the interest of the students (and even the instructors!). Labels were used to describe the function and destination of links, and back links to the starting page or high-level site categories were included on every page.
- Although frames seem to be a useful approach to reduce download time and to keep students visually focused, their use is not generally considered to be good design practice. In the design of *Wired Class*, there was concern about the ease with which frame-based resources or documents from other Web sites might distract learners and cause them to link out of the learning environment. Other problems with frames are that they cannot be bookmarked within the learning environment, their pages are difficult or impossible to reload/

refresh, and in-site and Web search engines cannot easily search their contents.

Information Presentation

Whether an instructional Web-based learning environment is based on vendor learning management systems or home-grown implementations, the instructional designer has many options regarding the nature of the content presentation. The importance of a well-designed user interface is that it facilitates and improves the performance of learners in using the Web and helps them to focus their attention on studying and learning the information more closely (Najjar, 1998). Effective use of color, for example, can give the learner a good first impression of the site content and encourage his or her acceptance (Najjar, 1990). In addition, graphics and symbols are the most visible elements on the Web and if they are simple, well labeled, consistent, and displayed with an optimal resolution, they can increase learner motivation and concentration (Pellone, 1995). Similarly, the clear, uncluttered, and consistent layout of instructional screens makes the learners' task easier and helps them to focus on the content. Experience garnered from *Wired Class* revealed a number of other issues:

- Students do not like to scroll long pages; this implies that consideration should be given to optimizing the length of course pages when designing online material. Tradeoffs may need to be made regarding the relationship between optimal lengths of content display versus page download times. While it may sometimes be desirable from a learning standpoint to present larger amounts of content in one page, that benefit may be neutralized from lengthy page download times that negatively affect learners' perceptions of the overall learning experience.
- Another "lesson learned" with *Wired Class* concerns the design of image

labels and captions. Students are familiar, from textbooks, with the use of captioning to provide brief descriptions of images, but this technique is inappropriate for visually impaired students who may require a screen reader to identify images. A guide for addressing this issue can be found at the U.S. Department of Justice's Section 508 Website (United States Department of Justice) which states:

Section 508 ... requires that Federal agencies' electronic and information technology is accessible to people with disabilities, including employees and members of the public.

Section 508 establishes requirements for any electronic and information technology developed, maintained, procured, or used by the Federal government. The term "electronic and information technology" has been defined by the Access Board in regulations published December 21, 2000.

In general, Web-based images such as those used in *Wired Class* require a precise and meaningful labeling strategy appropriate for students with special needs.

- Macromedia Flash is a popular tool for Web page design, but as Nielsen (1995) claims, its use in Web-based learning content requires careful consideration. For example, some browser buttons/functions (e.g. back, find in page, and font size) do not work within Flash. This can affect visually impaired students who may have to enlarge font sizes or search for specific words on the Web site. With Flash, hyperlink colors do not work consistently, thereby potentially affecting learners' perceptions of what they have seen or where they have been from links they have visited. Therefore, if Flash is used, for example to enhance interactivity, course designers (and students) must be made aware of such issues.

- The use of the Adobe PDF (Portable Document Format) has become widespread on the Web to distribute documents that must retain their original formatting. However, PDF documents are static and do not support interactivity and dynamic effects such as are possible from online Web pages. Instructional designers need to weigh the convenience of making materials available in PDF format against the more difficult to develop but pedagogically more valuable features of interactive Web pages. PDF should be used only if a large amount of information needs to be distributed and printed rather than read online.

Standardization of the Learning Environment

One of the issues that concerned *Wired Class* developers was how to ensure course material and client configuration (hardware and software) compatibility without precluding the use of Windows or Macintosh computers. An advantage to Web browsers is that, from a hardware platform standpoint, they are ubiquitous. Unfortunately, that is not true among different versions of browsers. A decision was made to try to use the most up-to-date browser functionality in the courseware while providing as broad base of access as possible to users of different browsers or versions of browsers.

Important tradeoffs had to be made to realize this goal, as creating text-only materials accessible from any browser would deprive students of many interactive capabilities of Web-based technology (e.g., style sheets, Java Applets, Java Scripts, ActiveX, and plug-ins). Developers compromised by using a minimal number of Java Scripts and Java Applets (for interactivity) accessible by Internet Explorer and Netscape Communicator browsers, both of which support Java Scripts and Java Applets. On the other hand, while ActiveX is a very useful, easy to use, and cost-effective tool for

Web development, it was not used because it is supported by only by Internet Explorer.

Because no incompatibility issues were reported by *Wired Class* users, it can be concluded that:

- Standard HTML language, which is 100% compatible with all Web clients and standard Java and Java Scripts, is the best way to ensure that pages are compatible with browsers. Web browsers interpret the latest HTML tags, particularly Dynamic HTML (DHTML), differently, and do not support all types of scripts.
- Compatibility is essential, not only among different browsers, but also different versions of the same browser. New versions of browsers have features (e.g., cascading style sheets or DHTML) that are not available in older versions of the same browser. To reach the largest possible audience and to take advantage of DHTML, Web-based instruction should be designed in a way that takes advantage of the advanced features of DHTML while still maintaining compatibility with older browsers.
- Using standard client-side and server-side programming languages (e.g., Java Scripts, Java, and CGI Scripts) may be more useful than using cutting-edge technology (e.g., ActiveX, Flash, Shockwave, etc.) which requires additional software (plug-ins) to be downloaded and installed in users' machines. Browser incompatibility with different operating systems (e.g., Macintosh, OS2, and UNIX) reduces the value of many of the new functions that vendors release on a continuing basis.
- Although a screen resolution of 640 × 480 pixels displays less material than a resolution of 800 × 600, frames, pages and graphics should be optimized for Netscape Navigator 3.0+ or Internet Explorer 4.0+ at a resolution of 640 × 480 pixels.

- A workstation's operating system affects how colors are displayed; therefore Web pages should be designed to use only 216 colors, the common base for both Windows and Macintosh.

CONSIDERING THE COST BENEFITS

Decisions are often made to use new technologies such as the Internet in order to reach a wide population of learners for less cost than would be incurred using traditional instructional strategies (Inglis, Ling, & Joosten, 1999). However, from analyses of *Wired Class* cost elements, it was not possible to conclude that this is always the case. Internet-based instructional delivery costs are a function of many factors, some of which include the purpose of the distance education program, the nature of the learning objectives, the pedagogical approach, the quality of learning materials, the lifetime of the materials, and student enrollments.

Cost factors that need to be considered can be categorized as capital infrastructure costs, course materials design and development costs, and instructional delivery and support costs. Cost analyses are meaningless unless cost comparisons can be made between the technology-based delivery scenario and some other comparative base such as a traditional classroom environment. However, while it is reasonable to *construct* a framework to estimate costs of online learning based on each of the three cost categories, it might not be useful to *compare* these, one by one, with those of other instructional modes, such as classroom instruction. Consider, for example, that online learning requires a substantial investment in hardware, networking, software, and support training, while more conventional print and audiocassette programs are much less expensive to create. However, the higher investment required to create the online learning environment might be dramatically offset by the high cost of creating and supporting traditional

classrooms in which the lower cost instructional materials would be used.

In *Wired Class*, a factor in the development and support costs was a desire to use high-quality online materials. Multimedia objects and interactive segments (e.g., input forms, interactive maps, etc.) were incorporated into the learning materials with the intention of improving student performance. More planning and programming time was needed to produce these materials than would have been required if only simple textual materials had been developed, and to develop the interactive materials required both the licensing of expensive and sophisticated production tools as well as employing skilled Web developers to use them.

However, the results of this study and previous research (e.g., Joy & Garcia, 2000; Spencer, 1999; Whittington, 1987) indicate that the use of interactive multimedia technology may not always enhance student learning. Spencer (1996) reviewed the effectiveness of media attributes in student performance and found that, overall, audio or visual media (e.g., radio, films, and television) that require expensive equipment, much time to develop and maintain, and skilled producers, may not improve student performance when compared with other static and low-cost media (e.g., textbooks and filmstrips). The information provided by these media "is often too much, in quantity or speed of delivery, and the student perceives only a fraction of it, and understands even less" (Spencer, 1999). Online developers should not assume that students will learn better from technology-based delivery systems. Rather, they should focus on instructional design strategies, regardless of the medium they choose (Joy & Garcia, 2000). Unless the use of multimedia (e.g., motion, sound, three dimensional images, simulation, etc.) to present specific concepts or skills (e.g., language) is considered to be essential for students to understand processes, achieve course objectives, or reduce study time, textual materials may be more cost effective than media-

rich online materials, particularly for small population courses (Inglis, 1999).

It is not clear that even when high quality and/or sophisticated presentation is considered to be essential, that online learning is more reliable and efficient than if CD-ROM-based materials are deployed. The significant and recurring costs associated with Internet hardware, software, and network support as well as those concerned with administering and supporting online students may mitigate the cost savings that might be expected from using the Internet. In CD-ROM delivery, the ratio of fixed costs to variable costs is quite high, as the costs of delivery are much less than the development costs, thereby allowing for potential economies of scale to be realized (Inglis et al., 1999).

In *Wired Class*, the ratio of fixed to variable costs was relatively insignificant and offset by the high variable costs of support. This resulted from the design objective of maximizing the participatory role of instructors and facilitators to manage the learning environment, to solicit and monitor student participation, to process student inputs, and to respond to students' questions, and so forth. These activities can cause instructors to invest significant time in ongoing instruction, making the operating costs of even relatively simple online materials higher than those of print (Rumble, 2001).

Because offering distance students the opportunity for dialogue with the instructor is critical for social and academic support and reducing drop-out rates (Simpson, 2000), both synchronous and asynchronous communications should be implemented with care. Synchronous requires fast (expensive) connectivity and highly-paid staff to arrange, moderate, and conduct live discussions. This raises the issue of the number of students that can be effectively supervised per course or per hour, and how these hours can be reduced without affecting the quality of learning (Rumble, 2001). However, asynchronous requires much time and also highly paid staff for planning students' activities and providing quality

learning materials. Therefore, the best way to increase the ratio of fixed development costs to variable costs is to reduce instructors' levels of involvement and minimize student-instructor interaction. This can be done by using self-study and self-assessment materials, and by encouraging students to support each other via online discussions. To do this, students may need to spend more time learning from the online materials and from peers who substitute for instructors.

Other ways to reduce the per-learner effect of fixed costs are to spread the costs over more learners, maintain the instruction for more years, and/or offer more courses on the system in which the fixed costs have already been invested. Increasing course enrollment should be considered, if possible, particularly if the fixed costs of establishing the learning environment are higher than the variable costs. Extending a course's lifetime (for example, for 5 years), and deploying additional courses in the learning environment can spread the fixed costs of course development over a larger number of students, allowing the cost per student or study hour to decrease significantly. Moreover, by increasing the number of international enrollments per course, the potential for economies of scale can be exploited to offset online delivery costs when compared to the costs of copying and distributing CD-ROMs or print to world markets (Inglis et al., 1999).

Another set of cost factors that must be considered are the costs of *receiving* online instruction in the home or school. Access or reception costs include the costs of purchasing computers, support software, and cost of the Internet connectivity (e.g., modems, Internet service providers, phone lines). These costs should be considered as an integral part of all cost analyses, particularly in countries with poor and/or expensive network infrastructures.

Overall, the *Wired Class* experience revealed that it is unlikely that cost savings can be realized from converting traditional instruction to online Internet-based instruction. The design and development costs of highly interactive and high-quality online materials are

less or similar to those for print/interactive CD-ROMs, but the variable and recurring costs of maintaining online materials, supporting, assessing, and administering online students, administering and connecting to Web servers, as well as the cost of student Internet access, can be significant. Instead of reducing costs, online learning systems can be more expensive than traditional instruction. However, if there is a need for Web interactivity and global access to the Internet, that need must be weighed against the inevitable costs described above.

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