"Advanced Systems Use for Safety Training Support: the role of OFF- and ON-line multimedia solutions in the education process both in the schools and in the companies"

"I sistemi tecnologicamente avanzati di supporto alla formazione ed informazione ai fini della sicurezza: il ruolo delle soluzioni multimediali On-line e Off-line nel processo educativo sia nelle strutture scolastiche che nelle aziende"

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ABSTRACT

The authors will explain how the correct use of the recently-evolving information technologies is able to drive a company towards a decisive rationalization of the training activity complex. They will also underline that the strength of a global safety management system could be optimized if a portion of the current safety training activities is taken from the industries to the school, overall at academic level, with the use of the proper communication tools, such as off-line multimedia (Cd-Rom Based CBTs) and the new on-line technologies (interactive training modules based on intranet networks or on the Internet).

It is very important to underline that nowadays many aspects of human life are strongly influenced by the Information Technology that in the last years has grown significantly in the fields of both hardware and software. For this reason an increasing number of increasingly sophisticated and flexible applications and software packages are used to better satisfy human needs. We will focus in particular on the role of advanced and computer-based technologies as innovative systems for safety training support.

In the last few years, the general spread of the new Information Technologies around the world and into society (both in the business and entertainment fields) is due to the discovery of computer-based multimedia and the more recent discovery of the Internet medium itself. Modern PCs allow the user to access all these media at the proper speed, while only few years ago it was impossible to view a video file on a normal PC without buying a very expensive decoding add-in card. We can underline the fact that the normal UIs (User Interfaces) are now referred as GUIs (Graphical User Interfaces) since all the Operating Systems are becoming more graphical and intuitive for the end user; thus, they are easy to learn and to use by the general public, not only on the Windows and Macintosh platforms but also on the UNIX workstations.

The same desktop applications are changing from pure text-based applications according to this graphical way of thinking, and they are often developed with the most recent visual RAD tools (Rapid Application Development, are becoming more intuitive due to the large use of a number of media (images, graphs, photos, sounds, animations and video) in application interfaces themselves, perfectly integrated into the graphical Operating System. This visual way of coding and graphical approach to the development of applications is driving towards a better representation of reality itself, which, of course, is multimedial. Thus, modern CBT is much more powerful than the old hypertext, since it can can incorporate a lot of media of different kinds to represent the content of the work, and not just text. This is more realistic for the end user, since each multimedia resource is chosen by the author in the typology that is best suitable for the specific information that has to be conveyed.

We can now quite effectively represent the real world with multimedia (sounds, video, and so on), and even the procedure of creating multimedia based apps is easier for an increasing number of programmers, who may now be more content specialists than code-writers. Each day a new compression codec is being analysed, so the multimedia production, both for education and entertainment is growing a lot faster. The most recent multimedia works also include new simulation and virtual reality technologies, since consumer application developers are now taking ideas even from the artificial intelligence field in order to better represent reality and succeed in creating real education tools with both a better representation of real life and better interaction with the user of the package, while only few years ago AI, simulation and virtual reality were terms used only in a scientific framework.

The same technologies have already been used with proven results in the safety framework too, for example as a way to better represent the results of complex mathematical modelling of accident scenarios coming from fires, to teach emergency procedures in response to them, or to explain the causes, the effects and the development of those scenarios to people not acquainted with safety and mathematical risk-modelling.

The safety field is now reacting also to the general spread of the Internet. In fact, in advanced countries, a lot of government safety organiziations and associations have their own web sites, where they post information on the most recent issues on safety matters, and provide a lot of excellent support utilities such as FAQs, newsgroups and even direct real time chat sessions among users. These services are studied by the general public, safety managers, employers and independent consultants.

This paper focuses on safety education and training, since it is quite important understand how to use all these new technologies for this kind of training with positive results in a period where the general public is becoming more involved with Information Technologies, and also in the schools it is now quite easy to find PCs to work with.

It is notable that disasters do continue to occur in the Chemical Process Industry, while similar accidents have already occurred in the recent past. Safety is crucially dependent on management and management systems, but conventional on the job training approach is no longer applicable, and all these constraints, coupled with the new compliance requirements of major hazards legislation in Europe and in the USA, oblige the management to identify new advanced solutions.

There are references to the number of incidents, disasters, and heavy losses due to lack of sound management procedures:

_ the inquiry into the Piper Alpha disaster (L. Cullen 1990) states (…) safety is crucially dependent on management and systems (…).

the report of CEC (G. Drogaris 1993) states: (…)

The conclusions of several accident investigations or studies on safety-related issues often show that similar lessons had already been learned a few years before in similar accidents. This indicates that, although the knowledge needed to prevent major accidents and/or to minimise their consequences is often available, there is:

a) a lack of the proper safety culture to enable effective use of this knowledge; and
b) a lack of a structured communication system to disseminate this knowledge. (...)

Another expert (I. Nimmo 1996) underlines:

- in a short period US CPI suffered 24 incidents; 12 deaths, hundreds hurt, $ 1B + losses, $ 10B + impact;
- Recorded Accident causes:
    * Human Error 85% (people 10%)
    * Equipment 15%

people (mistakes), Research, Design, Construction, Installation, Operation, Maintenance, Manufacturing, Inspection, Management

At European level:

- a major step toward a new comprehensive approach to Process Safety Management took place with the European Directive 82/501(4) which has been implemented into the national legislation of the EU member states with minor differences due to local safety legislation frameworks;

* a second step forward has been the position taken by the European Parliament
* a third major step has been the adoption of the EU framework Directive 89/391 (along with many others) .

The CURRENT legislation then points out clearly the need for effective and periodic safety training:

- The employer has to assure the training and the participation of the workers and of the workers' representatives in safety and health matters in the work place, and the employer has to give them effective instructions for operating the machines and the apparatus in the correct way.
- The worker must observe dispositions and instructions from the employer, the managers,…, for the collective and individual safety. The worker is supposed to properly use: machines, tools, substances, hazardous chemicals and of course PPE (Personal Protective Equipment).

The worker also has to play a propositive role in pointing out the needs with regard to safety in his workplace, to help managers and employers better understand the reality they manage, and to provide rapid, appropriate solutions to the possible risks. The paradigm of training can be expressed as a flow coming from the employer towards the worker, who has to be trained to do his job without being being exposed to risks.In fact the employer, in the training matters, has to:

- give instructions for operating machinery and combat possible and abnormal situations;
- assure periodic training (for example because of the introduction into the workplace of new machines/chemicals, or because of changes in workplace personnel).

The worker, on the other hand, in training matters, has to follow those instructions coming from the employer and the company management.

Since training starts from the employer, and he has responsibility for all safety matters inside his companies (as well as accidents and injuries), general managers, helped and supported by their companies' safety managers and by the medical personnel, have to assume a proactive role in pointing out how the correct use of the recent information technologies is able to drive companies towards a decisive rationalization of the training activity complex.

In fact, training inside companies is becoming more and more sophisticated. It also has to be conducted according to the new legislation both at national and European level as an integrated part of the quality system of the company (ISO 9000). Then safety becomes part of the global quality, safety and environment management system. Thus, the worker has to be informed about multiple aspects of life in the company plants. For example, in a petrochemical plant he is supposed to have the proper knowledge regarding instrumentation, procedures, risks, chemicals, accident scenarios, emergency and evacuation, first aid, …

All these aspects have to be taken also to minor workplaces and situations and are not to be considered (as they were some years ago) as applicable only to the major risk industries. Also, they have to be taken to public and civilian buildings such as educational structures (schools, universities, …). In fact, for these minor situations the legislation introduced the concept of risk analysis, prevention and protection. These recent laws did not introduce anything new with regard to safety matters, but they succeeded in proposing safety issues in a clear and explicit way to the general public, and they also underlined the importance of the proper training at every level.

For this last reason the paradigm of the employer-worker relationship in training matters also has to be taken, with the proper modifications in terminology and content, to smaller production firms, to the schools and to domestic environments. The schools in particular assume a very important and relevant role in safety education since they are the critical point of the public education framework. We have to note that students today, in particular those attending university, will be the workers of tomorrow at the companies we have already considered, and there is even the possibility that, from the universities, they will have to take on responsible roles in the matter of safety, as general managers, directors, safety managers, doctors, workers representatives,… For instance, a lot of engineers will probably be found tomorrow as safety experts and independent consultants for engineering companies.

Accordingly, in the training paradigm, the figure of the student in a school is similar to the figure of the worker in a company: the educational structures have to do safety training, since they are primarily educational, but also, because the student has to face risks even in school, he is supposed to have, also at that level, the proper training on safety, prevention and protection matters. The risks faced are often quite similar to the risks that students will have to face in the real and future workplace: it is enough to consider professional schools and laboratories,…

The magnitude of the risks is obviously reduced, but often in the correct proportion, so that without the proper training, they can be subject to severe injuries, since students are in a closer contact with these risks. Significantly, too, it is possible demonstrate that the effects coming from an accident scenario could be severe from a simple, even stupid, cause, if this is underestimated for lack of training (as in the case of a small fire that is uncontrolled at the proper time, where it would be possible to deal with it without any problems with portable extinguishers).

Therefore, considering the reality of a student laboratory of chemistry in a university, it is important, as is already done in companies, to understand both the possible accident scenarios and the emergency procedures in response to them (use of PPE's, fire fighting, first-aid, evacuation,…). Training has to deal with all these aspects and, for the study case, in particular with machines training, specific operations training, chemicals manipulation training and lab structure and safety systems training (all aspects that have a correspondence with training in the real workplaces where there are special documents (often legally mandated) to comply with these areas, such as the operative manuals).

It is important to underline that the paradigm of training as a flow of information from the employer to the worker has to be adjusted in order to take into account these considerations:

1) The information the employer has to supply his workers are not always prepared by him personally, since (also for legal reasons) there are other figures that support him in giving the right information. This help for example comes from the company safety manager, company doctor, private safety consultants and also from experienced workers in some cases (the company veterans that every day train new workers on the job).
2) The employer, as well as the company, needs a proper method to collect all the information coming from the many previously-quoted sources, to integrate them and to organize them (to avoid duplication of data or inconsistencies, since the flow has to be simple, clear and direct), to manipulate them and to deploy them to the public in the proper format.

In fact the worker needs a proper interface for this flow of information to understand it and to apply it.

The collected and organized training information has to be easily heard and understood. In this sense the employer has to find the methods and, eventually, the right tools to enable the correct dialog with his workers. The workers themselves have no specific knowledge in safety matters (They are not supposed to read an emergency plan or an operative manual themselves, but they are supposed to follow the instructions given by the manual if taken from it and conveyed in the right way, increasing their comprehension without decreasing the quality of the content). The workers also have limited time to devote to safety training, since there are a lot of other important training sessions they have to attend at (for example the specific training regarding the production and the machines), and all the training activity has to be conducted during the day hours, so we cannot imagine workers attending training sessions all day without doing their real work.

We can consider the educational framework in the same terms.

Case Study: Chemistry II course experience at Politecnico of Milano

It is the policy of the Politecnico di Milano to maintain a safe and healthy work environment for each employee (including student and contract employees), and to comply with all applicable occupational health and safety regulations. The Politecnico has established committees which share injury and illness prevention responsibilities both at Faculty level and at department level. Likewise, the Chemistry Department is committed to maintaining a safe and healthy work environment for all of its employees in all of its work-related activities. A specific Program has been developed which is intended to establish a framework for identifying and correcting workplace hazards within all laboratories with specific emphasis on the one devoted to students.

In this context we developed the project of integrating courses having laboratory activities with specific training on health and safety. Because the Chemistry II course (covering inorganic and analytical chemistry for chemical engineering students) is the first course having an experimental laboratory, we exerted the highest effort here to ensure that the involved staff and students receive appropriate training on the specific hazards of work they perform, and the proper precautions for protection against those hazards. Training is particularly important for young students whose sensitivity to problems of hazard is low and whose knowledge of procedures and hazardous chemical materials can easily be underestimated. This being the first contact with these problems, a broad approach was adopted.

First, applicable health and safety regulations, laboratory policies, and established work practices have been specifically developed for the activities related to this laboratory. These include but are not limited to:

- Observing health and safety-related signs, posters, warning signals and directions
- Reviewing the building emergency plan and assembly area
- Learning about the potential hazards of assigned tasks and work areas
- Taking part in appropriate health and safety training
- Following all safe operating procedures and precautions
- Using proper personal protective equipment
- Warning coworkers about defective equipment and other hazards
- Reporting unsafe conditions immediately to the teaching assistant (TA) in charge of the lab or to the course instructor, and stopping work if an imminent hazard is presented.

Second, some general problems of communications, information and laboratory practices were analyzed and alternative solutions were checked for applicability. After two years of testing, a training program was adopted which includes classroom, laboratory and home work with the support of multimedia information technologies. The classroom activity covers the fundamental aspects of health and safety regulations, a safe and healthy work environment, and safe laboratory procedures for working with chemical elements and their simple compounds. The activities also include the opportunity to deepen some visual aspects and review lessons and searching procedures on PC through both the Multimedia classroom service at the Chemistry Department and through Internet access at home. The activities in the laboratory (10 sessions of 4 hours each) cover a critical analysis of procedures applied, careful testing of established work practices, waste management, analytical determinations, etc. A report of all experimental and theoretical activity adopted in the laboratory must be provided to the course instructor on all these points for the final evaluation.

The training activity covers the following aspects:

1) Laboratory safety policies (appropriate use of personal protective equipment, laboratory glassware use, use of analytical instrumentation (including balances, hot plates, drying apparatus, Gas chromatograph, IR and UV spectrophotometers, etc.)

2) Hazard communication: health and safety-related signs, posters, warning signals and container labeling

3) How to obtain and use MSDS information on chemical compounds from Material Safety Data Sheets (MSDS) (hard copies and online copies accessed through the Chemistry Department web page - Chimica2) designed especially for laboratory workers (they provide concise critical discussions of the toxicity, flammability, reactivity, and explosibility of 200 chemicals used in the Chemistry II laboratory). They cover the following 16 articles: a) Identification of the substance and manufacturer; b) Composition/information on ingredients, c) Hazard identification, d) First aid measures, e) Fire-fighting measures, f) Accidental release measures, g) Handling and storage, h) Exposure controls/personal protection, k) Physical and chemical properties, i) Stability and reactivity, l) Toxicological information, m) Ecological information, n) Disposal considerations, o) Transport information, p) Regulatory information, q) Other information

4) How to obtain and use MSDS and Hazardous Materials Handling Procedures from all Data available in the Chemistry department, and on line on web sites or databanks. These last include the following useful general sites:

* European Center for MSDS Services
* Vermont SIRI (Safety Information Resources on the InterNet) Web Site
* Chemical Abstracts Service
* Chemfinder Database Searching
* The Fisher Scientific Internet Catalog
* ECDIN (Environmental Chemicals Data and Information Network)

Examples of use of catalogs and web sites of Chemical Manufacturers and Suppliers (Sigma, Aldrich, Fluka, Acros, ecc.) and of manufacturers whose primary business is not chemicals is also presented. .

5) Fire prevention techniques and fire extinguisher use (including a visit to the general stock deposits of chemicals and solvents of Chemistry Department and to a compartmented room for organics).

6) Asbestos & heavy metal awareness

7) Water waste collection and waste management (including an example of inertization and a visit to equalization equipment and waste analytical control at the Chemical Department)

8) Gas handling and use of pressurized containers (including a visit to the gas central deposits and gas distribution equipment in the Chemistry laboratory)

9) Comparison between different chemical transformation with different waste charge and process decisions (an introduction).

10) Analysis of European and Italian health and safety regulations (an introduction).

Computer Based Training: Industrial and Educational Approach

We are convinced that the method the employer is looking for to optimize the training information flow (not only in the field of safety) could be an ad-hoc information technology system, able to manage and deploy data to workers. Some big companies, mainly in North America, have already understood the need to use a computer-based management system to comply with these needs and to solve these problems.

A system has to grow in relation to the training needs at low costs in the future, unlike a static electronic book or a simple document management package. A software solution has to be considered, inside the company, as a production plant that has to change in the future to solve new problems and to deploy more information. These experimental systems have, in their architecture, the features both of large databases for different formats of content (images, sounds, texts, …) and of multimedia visual development tools. The great difference between them and the usual dbs and development tools is that they are a lot easier use for the end users (workers) and it is a lot easier for the employer (or the people that support him in the workers' training, as mentioned before) to add new information, supposing they do not have the authoring knowledge of a multimedia applications developer. These systems are generally called: "Process Safety Management Support and Training Systems". With them, it is also easier to keep a schedule of training, to propose tests and quizzes to test the training people and to keep a record of all the training and tests completed by individual workers. They also work on LANs, and are able to handle more development workstations and hundreds of student platforms.

As already noted, the same paradigm of information flow can be taken from the industry workplaces to the schools, with the proper modifications. Even in the school it is important to build a layer, based on a proven and effective method, to make the safety informations flow through the paradigm from teacher to students. The deployment of information in the educational structures raises the same problems encountered in the companies and in the real workplaces and so it can be solved or supported by the use of similar training methods.

In fact, even in the educational structures, where we identified the same kind of risks, the same accident scenarios with the correct proportion:

- safety is an "add-on" to the real educational courses (even in the universities);
- resources to prepare educational safety courses are much reduced both in terms of people and available time;
- the audience is quite different, and in particular the age of the audience influences the way information is deployed;
- the systems for deploying the collected information are not as up to date as they could be in a company where there is always, for other needs too, an information technology framework, and there are available budgets specifically for safety training.

However, our view is that the use of multimedia tools, such as the ones used by companies, in the proper proportion can be a solution for these needs. Overall a multimedia method to develop information and deploy it is suitable for the particular age of the audience in educational environments. Students working in chemistry laboratories are always young people, and they live in a multimedia society constantly in close contact with multimedia sources of information. They are usually comfortable with PCs and software packages in general as they generally use them at home to study and to entertain themselves. Often they are skillful in surfing the web to look for information, and they are already able to use the new Internet interactive pages, built with some of the technologies that will be explained later.

Multimedia packages, both off-line and on-line, are the best solution to present safety information to this audience. This age-group requires particular care in visualization of information, to give them a better representation of reality. It is more stimulating for them to see a video with sound showing what will happen if a fire starts in the lab and what has to be done in that case, than to read a describing the same scenario in a classroom. Their memory about safety matters has to be trained with the proper media, and they are likely to mantain this knowledge with the associated images for a very long time.

The best format to deploy multimedia content is clearly the CD-ROM, which is shortly due to be superceded by the DVD-ROM for better performance. The CD is recognized as the right tool to give enough space to build interactive pages with a lot of graphics as requested by the training of non-specialized people and young people.

Writing a multimedia application can be as simple as filling boxes with different information, choosing which is the best media to represent the information itself, then linking information and media through a general hypertextual interface. Multimedia applications on CD-ROM act like a prism, organising all the information prepared by the developer in the media he has choosen to present them to the public and giving them to the end user as a single homogeneous flow of information. In a training application, such as the one developed for the student lab, it is possible to find information about several aspects such as safety information, operational/management/emergency procedures, training lessons and quizzes. The information has been developed in the various media formats, choosing the proper media according to the audience's knowledge and background, and considering the possible reactions and responses. Media formats may include text, images (photos, CAD diagrams, drawings, flow charts, and even cartoons) in 2d/3d, sound, video (2d/3d animations, digital video), SQL databases (using dbs inside the application itself and/or links to exterior dbs already available).

The different media, representing information, are like objects linked by the general framework of the application, written as programming code by the developer. The framework is based on the theory of hypertext (a familiar interface to all people who surf the web looking for information). The frameworks has been coded as a hypertext to give the end-user the possibility of avoiding the common path through the documents and the different medias and to allow him to choose how to surf the content by himself.

He can then take a path through the material stimulated by curiosity, a specific lack in knowledge or a particular need coming from having seen an object and wanting to investigate more about that information.

This framework allows each student, based on his needs, to have a personalized path throuh the information and thus a personilized path of education. The individual pieces of information, coded in the same way for all the audience, are standard and are independent from the teacher. A training session can be suspended and restarted later, and the information can be seen again as refreshment. A dbs inside the package, such as the one about the properties of hazardous chemicals, can be used when the student has a need, and the quizzes allow the student to verify comprehension after a training session. Of course, packages for training should be coded to allow the teacher to make a lesson based on that material in a sequential display as a common, generally agreed path: for this purpose, free slides which the end-user can freely flow through can also be presented also in an automatic and temporized way, like a television show. The teacher is able to stop the slide-show in any time to start a new path with a deviation to follow specific students needs, to underline information by showing other more detailed and in-depth information related to the topic.

Nowadays a lot of companies are developing such multimedia packages for custom needs, and also some safety consultants companies offer this as an integrated service for their customers, giving the CD-ROM free of charge together with the paper work they are paid for with the sources of information in electronic format, also including the development of the entire package if necessary. In this case the developer is able to start from scratch, from the paper where the information is already linked to follow a general path, and from the electronic version of the same information, as it was treated by the consulting company to build the document.

It is important to note that nowadays PCs are able to run a multimedia package, although for long performances, at close to TV quality, the PC should be expanded with particular video/audio cards (which are not too expensive lately). The CD-ROM-based training material can be delivered over a LAN, since it is quite common to find networks in the universities. In this case, it is possible to have a master PC (the teacher's machine) that takes care of the projection of the media on the wall to better represent them to the students, and also acts as a server to store historical data regarding students' training sessions, quiz results, and so on. It is a good idea to use a common path for a projection on the wall and then allow the students to go into classrooms with PCs where the same package is at their disposal for an in-depth analysis and for free paths through the different media.

Many development tools allow the developer to focus more on the content than on programming. Often no programming skills at all are needed. It is useful in this regard to examine recent versions of the presentation packages that can be considered true development tools with proper runtimes, which enable the packages to run in machines where the authoring environment is not installed, generally at no cost. These give the developer, who may be a teacher able to use a common wordprocessor, a huge library of media to be used in their applications and a lot of wizards to simplify the creation of interactive pages and to reduce the time needed in the creation of an application based on a lot of information. The same tools have deployment wizards to allow the developer to port the work done in the proper format, ready to be distributed via CD-ROM, local network and often via the Internet. In fact, a lot of these packages allow the developer to write once and to run both off-line and on-line.

The teacher should also focus on the portability of his own package, since the machines on which it will run are not always built with the same hardware components and the results can be different for the end user from machine to machine. It is important to develop the application based on the general hardware configuration available, even if there are tools that convert packages between formats, and take care to adjust them in real time during the runtime.

Quite often, in an educational structure, it is possible for the teacher to be helped by the students themselves, who, as already said, are quite acquainted with the multimedia world and often with the programming languages. The developed system, like PSAMs in companies, is not intended to be coded once and then left as it is for long periods, but to be integrated with new information and even with new typologies of media if any, or modified in its framework and in its way of deploying information, in response to the comments of the students themselves, who become the judges of the package itself.

The CD-ROM in an educational framework mirrors the PSAMs in the industrial framework: it clearly has great differences in comparison to more advanced systems (it is not, for example, so flexible and so updatable as the PSAMs contents) but it is a good starting point to give students a different and easier approach to learning safety material.

It has been demonstrated that with a CD-ROM-based multimedia application it is easier to make the students understand how to operate emergency resources or personal protective equipment and how to conduct emergency procedures like evacuation. With a CD-ROM it is possible to show a video about the use of portable extinguishers, for example, with the real sound the extinguisher produces. Then it is possible to fragment the video into images illustrating the single steps of operation as still frames with a speaking voice instructing. Finally, it is possible to compose everything back into a video to remind the students about the use of portable extinguishers when they are skilled enougn in the single steps. Every time they see even only the video, they will be able to remember the still frames of the procedures. Obviously a multimedia application is not able to train someone as well as would be possible with real fire training, but it is certainly more impressive than a description on paper, a discussion or even the simple label put on the extinguisher body itself.

The most important thing is to recognize that for proper training the information has to be presented in the proper format depending both on the kind of the information and on the typology of the audience. The multimedia application is the only framework within which to collect and manage so many different formats of information, and to store them for later use, giving the end user a high degree of interaction.

The multimedia application is even substantially cheaper and easier to realize nowadays with the available development tools and represents a scalable solution towards future more sophisticated computer-based systems.

Survey of technologies for delivering interactive learning over the Internet

A range of different tools and options are available for delivering instructional content over the Internet (or an Intranet). This is a brief survey of the most significant, along with their strengths and weaknesses:

HTML (Hypertext Markup Language) is the oldest and simplest technology, primarily designed for the presentation of non-interactive documents. While HTML is changing all the time, all new browser programs (which display the documents) are backward-compatible, so by avoiding recent innovations in the language, authors can ensure that their documents can be viewed on virtually any platform or system. Documents may contain a range of text colours, formatting and pictures, but there are very limited possibilities for interaction: hypertext jumps and form submission are the only real options. Hypertext enables the user to click on text in the document and jump to another document or another part of the same page; form submission enables the user to fill in an online form and submit it to a server or an e-mail address. These features of HTML can be "stretched" to enable some quite useful types of interactivity for instructional purposes. These are two examples from the Online English Writing Course at the University of Victoria:

http://web.uvic.ca/hrd/OLCourse/Unit_3/descrip3.htm (multiple-choice exercise)

http://web.uvic.ca/hrd/OLCourse/Unit_3/descrip5.htm (assignment submitted through a form)

However, simple HTML does not allow the programming of dynamic changes to a page in response to user input. This possibility is becoming more feasible with the use of Dynamic HTML (the combination of recent HTML innovations, scripting languages, and the Cascading Style Sheet standards). Dynamic HTML promises to allow sections of documents to be hidden and shown as needed, and text and pictures to be layered on top of each other. Combined with client-side scripting (see below), DHTML would enable sophisticated interactive documents to be created; in addition, text, layout and formatting can be controlled to a much greater extent than was previously possible, and the CSS innovations actually help to reduce file size by packaging formatting information much more conveniently.

However, DHTML is only implemented in the most recent versions of the two major browsers (MS Internet Explorer and Netscape Navigator), and, more importantly, it is implemented differently. Pages designed to work on one of the browsers are unlikely to display or function well on the other. This, combined with the fact that the majority of Web users have not yet upgraded to version 4 browsers, means that DHTML remains a niche solution to the problem of creating interactive instructional materials. If instructional designers can be sure that their target audience will be using a particular version of one browser, then it is possible to create excellent materials, but broader compatibility remains problematic. Few examples of the effective use of DHTML for instructional purposes have emerged at this point. For further information on DHTML, see Darnell et al.

A more reliable approach is to use client-side scripting languages to introduce interactivity into HTML pages. Client-side scripting is a technology which allows developers to write small "programs" which are embedded in Web pages (as text). These programs can respond to user actions such as clicking on buttons or filling in text fields. They can also be used to create new Web pages, which are dynamically written on the user's screen to provide complex feedback.

A number of scripting languages have emerged in the last few years, but by far the most common and widely supported is JavaScript. JavaScript is supported by Netscape Navigator and MS Internet Explorer, and complex scripts can be written in this language which will be supported on versions 3 and above of both of the major browsers. Some examples of the use of JavaScript for instructional material (mainly for language-teaching purposes) are listed below:

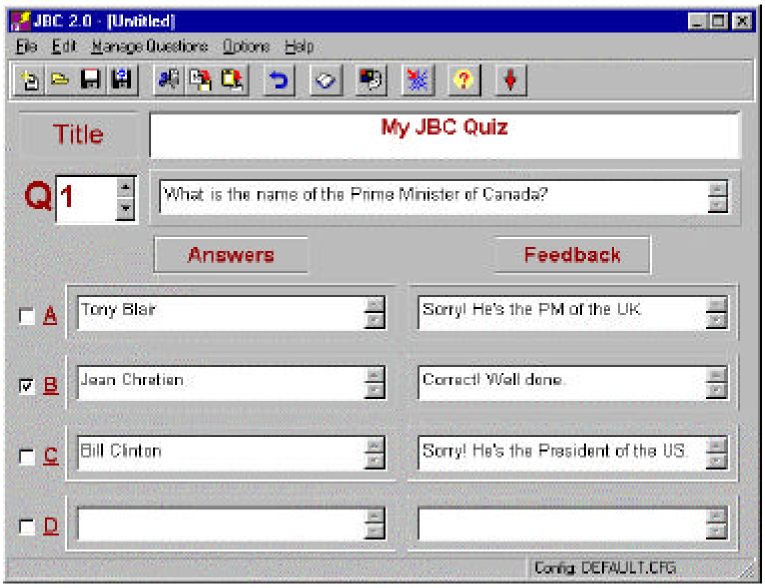
First-aid simulation exercise: http://web.uvic.ca/hrd/elc/firstaid/crash.htm
Multiple-choice exercise: http://web.uvic.ca/hrd/elc/410/grammar/gerinf3.htm
Text-entry (short answer) exercise: http://web.uvic.ca/hrd/elc/410/grammar/gerinf2.htm
Gap-fill exercise: http://web.uvic.ca/hrd/elc/410/grammar/gerinf1.htm
Matching exercise: http://web.uvic.ca/hrd/elc/weblang/weblang2.htm
Crossword puzzle: http://web.uvic.ca/hrd/elc/weblang/weblang22.htm

A complete online presentation on the use of JavaScript for creating interactive exercises is available at: http://web.uvic.ca/hrd/elc/weblang/

This kind of text-based material has wide applicability in many fields where self-tests or progress tests are an important part of learning. These exercises can be delivered to any computer attached to the Internet (or an intranet), and download quickly, since they consist mainly of text. No special server settings are required -- in fact, the exercises do not need to be located on a server at all; they could perfectly well be distributed on a floppy disk if necessary. This combination of compatibility, speed and convenience make JavaScript an excellent choice for many training environments.

For these reasons, it has been adopted by instructional designers all over the world. Code "templates" have begun to proliferate on the World Wide Web, enabling authors to create exercises simply by plugging their own data into someone else's code. Even with a template, however, creating an exercise can be difficult and time-consuming. In order to simplify the production of these types of materials, and make it possible for instructors who do not know HTML or JavaScript, Half-Baked Software (the University of Victoria Language Laboratory Research and Development team) have created a suite of freeware applications which produce several basic types of exercise automatically. The Hot Potatoes suite allows the user to type instructional content (questions, answers, texts etc.) directly into five authoring tools, and then create functioning Web pages simply by pressing a button. The tools are fully configurable in any language based on the Roman character set, so they can be used to create exercises in most European languages. The five applications have similar interfaces, so they can be quickly learned.

Figura 1. - This is a screenshot of the multiple-choice quiz generator, showing how the user can enter



questions, answers and feedback before generating Web pages.

More information on Hot Potatoes is available from the Half-Baked Software Web site at http://web.uvic.ca/hrd/halfbaked.

However, there are obvious drawbacks to using client-side JavaScript. The language itself is quite limited, and complex programming tasks can rapidly become unwieldy (as well as executing rather slowly on the user's machine). There is limited support for graphics, and user-interface features such as drag-and-drop cannot (yet) be implemented. Finally, secure testing and score-logging cannot easily be done. While JavaScript is an excellent choice for some types of interactive learning, self-testing and progress-checking, where a full course is to be implemented and delivered through the Internet, other tools will be needed to enable the instructor to monitor and assess a student's real progress and scores effectively.

Server-side scripting is one solution to this. Scripts can be written (also in JavaScript, PERL, etc.) which run not on the user's machine but on a server, and if these are used to process the user's input, the results can be logged and kept secure. Several large-scale educational environments have been created based on server-side scripting. Among the most successful is WebCT, created by the University of British Columbia in Vancouver. WebCT is a complete environment which enables instructors to create entire courses online, complete with quizzes and tests in which the student's scores are logged. Instructors need little knowledge of the underlying technology in order to use the environment, and services such as an integrated chat-room and bulletin-board facilities are automatically provided by the system for each course. Instructors can very rapidly convert ordinary course materials into Web-based learning, while students taking several courses in WebCT will quickly become familiar with the consistent environment and behaviour. A detailed introduction to WebCT can be found at http://homebrew.cs.ubc.ca/webct/, and descriptions of this and other similar tools can be found in McCormack and Jones (1998), Chapter 9.

There are two main drawbacks to an integrated system such as WebCT. The first is that, for interactivity to take place, the user's computer needs to be in regular contact with the server. After completing a quiz, the student's answers must be submitted to the server for marking, and the results returned.

This can take time. It also means that such materials can only be delivered over a live connection to the server; it is not possible to distribute them using floppy disks or CD-ROMs.

Finally, the consistent interface which is one of the strengths of this solution is also one of its drawbacks, since instructional designers (especially those with little technical knowledge) are constrained in the range of types of exercise or interactivity they can use. There may be a tendency for course material to be forced into the format of the WebCT environment, rather than for the structure and format of the materials to be dictated by the content.

Perhaps the most widely-discussed solution to online delivery of applications and materials is the Java programming language. Java was invented with the World Wide Web in mind, and it promises to be a way of delivering over the Web the same kind of rich and flexible user-interface as can be achieved when writing native programs for Windows or Macintosh environments. Complete applications can be programmed in Java and delivered to remote computers, on which they run as if they were native (albeit a little slower). Java is a powerful object-oriented programming language, and allows complex manipulation of graphics and mouse-events (such as drag-and-drop) which are not available through scripting. A good example of this is a fractal generating applet which can be found on the Open Teach Software Web site at http://www.opencollege.com/technol/Java%20Applets%20JDK%201.0.2/html/fractals/Fractals.html.

However, there are drawbacks with Java too. Many simple Java applets require large class files which take a long time to download. In addition, there are significant incompatibilities between the Java virtual machines (software environments in which Java programs run) implemented in different browsers, so Java applets frequently fail to run or behave erratically. As with DHTML, if a developer can be sure that users will have particular virtual machine or browser version installed, then he or she will have more chance of creating software which runs reliably. Meanwhile, the second generation of Java Rapid Application Development tools such as Borland JBuilder and Symantec's Visual Cafe, now proliferating, are beginning to offer developers the kind of powerful and easy-to-use development environments that have long been available for Windows programming, and it seems likely that this will spur the development of new Java applications considerably.

One final class of technology will be of interest to online training developers: proprietory programming solutions such as Macromedia's Director and Authorware, and Toolbook from Asymetrix. These development environments enable the non-programmer to produce interactive content quite easily, and are particularly targetted towards the production of multimedia content involving lots of graphics, video and sound.

Authorware, for example, allows an instructional designer to create an interactive presentation which incorporates sound, video, graphics and animation, and to package the product for delivery to a Windows or Macintosh desktop, or over the World Wide Web. In the latter case, a special browser plug-in is required, but once this has been installed the user should be able to view and interact with the presentation just as if it were running on his or her local machine or from a CD-ROM. Once again, there are some compatibility problems, and it can be annoying for users to have to download and install the special plug-in; in addition, the delivery of high-bandwidth multimedia content over the Internet is rarely efficient or effective, and it may be a long time before this delivery method can reliably replace the CD-ROM. However, these products have a large user-base in the field of education, and have proved their effectiveness over a long period of time. The Macromedia Web site (http://www.macromedia.com) has links to many examples of the kinds of material produced by Director and Authorware (although the Shockwave plug-in is required to view them).

All of the technological solutions outlined above have their own strengths and weaknesses, and all are appropriate for certain situations. If the content to be delivered takes the form of static documents, manuals or similar materials, then the best solution is probably HTML (or Dynamic HTML if users will have version 4 browsers). For small-scale mainly text-based self-testing and interactive learning materials, JavaScript is most efficient, especially using simple authoring tools such as Hot Potatoes. Where secure testing, score-logging and record-keeping is required, server-side solutions such as WebCT will be needed. Java can be used for specialized interactive training needs, such as mimicking control of a particular piece of technical equipment online, while multimedia-rich interactive presentations are probably best prepared using a tool such as Director or Authorware, and delivered via a browser with a special plug-in.

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