Journal of Universal Computer Science, vol. 2, no. 8 (1996), 580-595
submitted: 26/8/96, accepted: 26/8/96, appeared: 28/8/96 © Springer Pub. Co.

LATE: A Unified Concept for a Learning And Teaching Environment

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Abstract: LATE is the acronym for Learning And Teaching Environment, a concept that pulls together a number of developments in a uniquely integrated way to provide - for the first time in the history of computing - an approach to computer assisted learning and teaching that offers a realistic alternative to more traditional methods.
Above claim may sound exaggerated. However, the reader is asked to reserve judgement until having looked at the details of this paper. LATE is not just one other concept in the area of computer assisted instructional technologies - an area rich in projects with high-expectations but few real success stories. LATE is more: it is based on much experience with earlier undertakings, both negative and positive, and is positioned to be a definitive answer to educational needs as they can be provided by networked multimedia systems now and in the forseeable future. LATE is positioned as concept that can be turned into a fully functional and applicable system, open-ended to incorporate further modules, improvements and future computer and network technology. In this sense LATE can be aptly described by the longer acronym: IS THE LATEST, standing for Integrating Systematically Technologies Helping to Establish Learning And Teaching Environment Strategies.
It has been over 30 years that computer-based solutions for educational purposes have been investigated and experimented with. Results have been consistently exasperating modest. Indeed some frustrated researchers and developers have started to seriously consider the possibility that the educational process - being highly oriented towards individual needs - may not be computerizeable at all to a large extent.
The LATE concept as put forward in this paper - will show that above mentioned pessimism is - fortunately - not justified. Rather: it has taken a long time to effectively introduce computers into the educational process, but the LATE concept, once implemented, provides the ultimate answer. Hence our pun: LATE is better than never! And hence our request to all European funding agencies, and the European Commission in particular, to provide the financial assistance to turn LATE from a concept into a reality.
LATE is not a new attempt at developing a computer assisted instruction (CAI) or computer based learning (CBL) system; it is not a system providing modern lecturing techniques; it is not another attempt to implement digital libraries; it should not be seen as a novel authoring environment, a distance teaching system, a networked help system, discussion forum, computer supported collaborative environment or a networked model of modern computer based decision rooms. LATE must not be understood as any of the above: LATE is the rich symbiosis of all of the above resulting in an environment of breadth and dimensions sofar unheard of.
If this sounds too good to be true: do continue reading; above is not intended to give a project description, but to "whet the appetite" for reading what follows. There we will show that and how the symbiosis of the diversity of areas is indeed feasable when a modern WWW system with much extended functionality is used as a basis.

Key Words: WWW, Web, distance teaching, authoring, CAI, CBT, CSCW, educational software, HyperWave, Hyper-G, HM-Card
Category: C.2.4, H.2.8, K.3

1 The LATE Concept - General Outline

LATE (= Learning And Teaching Environment) is a concept that combines all important aspects of the use of computers in educational settings into a single powerful system that (a) provides a new and effective Learning And Teaching Environment based on current technologies and is (b) open towards new computer and network developments. It suggest to integrate existing modules in a flexible way as will be outlined establishing full bridging where appropriate.

LATE is based on years of experience with the use of computers in educational settings, on one of the most advanced "authoring and CAI" systems available called HM-Card [Maurer and Scherbakov 1996] and the first second generation WWW system Hyper-G/HyperWave [Maurer 1996].

Since LATE draws on a number of disciplines it can be understood as a powerful extension of diverse areas such as e.g. CAI (Computer Assisted Instruction), Authoring Systems, Hypermedia or WWW Systems, and Communicational and Cooperational tools within them, CSCW (Computer Supported Collaborative Work) and Digital Libraries [Marchionini and Maurer 1995], or [Maurer 1995b], to mention just a few of the more important components.

For the purpose of this exposition we explain LATE from the CAI point of view but have to and wish to stress that alternative views would be equally justified and illuminating.

In the remainder of this Section 1 we present a first rough idea of what the concept is all about based on a CAI perspective. In the following Section 2 we analyze earlier CAI efforts and their shortcomings; we explain in Section 3 how those shortcomings may be rectified by integrating a variety of ideas and techniques and explain how they could be combined in Section 4. Section 5 is a short summary and Section 6 includes some references.

As mentioned in the paragraph above we now proceed to explain the basic idea of LATE by starting with the CAI nucleus of LATE. We want to caution once more that CAI is not seen as more central to LATE than other areas; our choice of starting with CAI aspects is arbitrary but eases the description of the concept.

LATE contains a CAI (Computer Assisted Instruction) nucleus. This nucleus is basically WWW enriched by the features of HM-Card [Maurer and Scherbakov 1996] and other data-types embedded in WWW that require helper applications for viewing, such as e.g. PDF [Adobe 1993].

Thus, LATE allows the creation of "courseware", i.e. multimedia material with educational contents involving text, graphics, animation, pictures, audio- and videoclips, 3D images and scenes, etc. interspersed with "question/answer" diaglogues. For more details concerning above points see Section 2.

Note that courseware is usually educational material that is used in "double isolation" in the following sense: learners are isolated from other learners, tutors or teachers, and the material presented is a "closed universe" supposedly selfcontained, i.e. isolated from the universe of other material. In LATE, both barriers are completely removed: the first by embedding the courseware in a network that allows asynchronous and synchronous interaction, between learners, and between learners and teachers; the second by understanding courseware modules not as isolated islands but as parts of a large electronic repository of such modules, of executable software (e.g. "simulation" and "experimentation" components), electronic books, journals and a variety of other electronic material combined in a "Digital Library".

The removal of the barriers mentioned has many other synergetic side effects: "authoring" a course - an up to now tedious and time consuming effort - can often be reduced by fitting together existing modules of the electronic library by merely "customizing" them. This and the fact that such material can also be used in computer supported lecture rooms not only leads to modern lecturing techniques [Lennon and Maurer 1994], replacing traditional overhead transparencies but also leads to the concept of "authoring on the fly" [Maurer 1994, Ottmann and Bacher 1995]. The "usual" authoring-of-courseware bottleneck is virtually eliminated in LATE because of the new methodology mentioned above and the crucial fact that (!) potential question/answer dialogues do not have to be "guessed" by authors any longer. Rather, if questions arise that have not been dealt with before, LATE allows the automatic inclusion of the resulting question/answer dialogue that thus becomes part of the courseware for future use. As WWW based system LATE also is a natural candidate for use in distance teaching with desirable functions such as "on-line help" or "discussion groups" thrown in "free" due to the communcational and cooperational features inherent in its basis Hyper-G/HyperWave.

We have now provided a first glance at LATE. By analyzing weaknesses of traditional CAI approaches and showing how they can be overcome by adding new functionality (Section 2 and 3) we present two further layers of details of LATE before turning to the more technical Sections 4 and 5.

2 Analysis of Past CAI Developments

The first serious attempts to use computers for educational purposes date back to the early sixties. Despite expensive and unsophisticated hardware (text-only terminals with keyboard input only) some packages like PLATO although not successful on a grand scale continued to be used by some institutions for more than 20 years. The main reason for the comparative success of PLATO is due to its sophisticated record keeping system (useful for both student guidance and quality control), supported by the then popular arrangement of simple-minded terminals attached to a central computer system. There are three main aspects why PLATO (and similar systems) did not do better than they did that are usually quoted:

(1) bad price/performance ratio on the equipment side;
(2) lack of (colour) graphics and animation to better visualise processes;
(3) high effort to produce good quality courseware.

With the advent of personal computers points (1) and (2) changed dramatically and (3) improved due to so-called What You See Is What You Get (WYSIWYG) editors. This resulted in a new wave of enthusiasm culminating in efforts such as COSTOC and the first versions of Authorware.

To the surprise of many specialists, the new systems did not achieve the breakthrough expected, either. Careful analysis yielded the following reasons, this time:

(4) the decentralisation due to personal computers and stand-alone configurations annihilated one of the crucial successes factors of earlier systems, the careful record keeping of how students used what material;
(5) the cost of authoring systems (compared to, say, graphics editors) was unjustifiably high;
(6) production costs for good quality material remained high (typically 100 hours effort for one hour of instructional material);
(7) lack of sophisticated interactivity and insensitivity towards individual student needs: most courseware was still of the "page turning variety", students working in a "tunnel" from which they could not escape.

From 1985 onward, much effort was invested into point (7) by investigating, for example, "intelligent tutoring systems", "student modelling", extensive use of "simulations", etc. Success was limited due to the very high costs involved in creating good courseware this way; attempts to reduce the "tunnel" syndrome by introducing new navigational paradigms were partially successful, yet points (5) - (7), as a whole, remained sufficiently unresolved to prevent much success.

The most crucial change occurred in the late eighties with the emergence of true multimedia and the notion of "hyperlinks", allowing users to navigate fairly freely within a certain instructional domain. Tribute has to be paid to HyperCard (and its clones). Suddenly, inexpensive or even free authoring packages became available. Difficult to prepare vector graphics could be replaced by easily scanned images. Also, the "hyperlink" paradigm seemed to eliminate the feared "tunnel" syndrome. As a consequence, tens of thousands of educational modules using HyperCard and similar tools, or more recently Web tools, have been created.

It is instructive to realise why this new approach stimulated computer-based education but did not create the final breakthrough, either. Recent studies list the following reasons:

(8) since scanned images are so much easier to use than carefully prepared vector graphics (diagrams) they are often used even if vector graphics would be more appropriate for the instructional aim at issue;
(9) replacing the "tunnel effect" and "page turning" by arbitrarily free navigation leads to "getting lost in hyperspace" and disorientation;
(10) the use of images, video and audio clips increases data volume to an extent that network-based or floppy-based distribution becomes infeasible;
(11) preparation of small packages is easy: indeed easy to the extent that even those never having considered pedagogical or design issues suddenly believe to be expert courseware designers;
(12) it is not enough to prepare small courseware packages; large databases of modules, and re-usable, easily maintainable and customisable modules are necessary;
(13) courseware should be available both in stand-alone and networked mode.

LATE is the first coherent proposal solving all issues discussed in (1) - (13), hence packs into it much of experience of past 30 years of computers as educational tools. In conjunction with emerging large "digital libaries" and sophisticated communicational features we have reached a decisive point, the point where using computers to support teaching and learning becomes truly feasible.

To conclude this Section we analyse how progress in computers and features of LATE are assuring that the "13 obstacles" of (1) - (13) are no longer valid:

(1) price/performance ratio of equipment is no longer a problem;
(2) techniques for high quality visualisation are now available;
(3) the effort to produce good quality courseware has been reduced due to better editors and the use of media from various sources;
(4) decentralisation yet keeping detailed records of use is becoming possible by putting courses on the Web (WWW); this aspect is very important and explicitly addressed in LATE;
(5) authoring tools are either free (like some HTML editors) or inexpensive (like HM-Card);
(6) the concept of modularity, maintainabiblity, reusability and customisability as e.g. available in HM-Card assure that LATE allows more efficient authoring by orders of magnitude; also, "authoring on the fly" (see Section 4.5) may soon be a reality;
(7) LATE suggests to have as much navigational freedom and cross-references to other material as is desirable for the subject at issue;
(8) LATE recommends to use scanned images but to also provide built-in editors for vector graphics and animation, like e.g. in HM-Card;
(9) LATE claims and assures that both guidance and freedom are available;
(10) LATE allows all media but also enables the creation of very compact courseware modules suitable for the Web;
(11) LATE allows to emphasise pedagogical issues and standard formats;
(12) LATE is the first system supporting the four important properties: modularity, reusability, customisability, maintainability based on HM-Card;
(13) LATE supports stand-alone and networked (WWW) mode.

Since the possibilities of HTML 3.0 and PDF (PostScript) (see [Adobe 1993]) are well-known we do not discuss them here further, but HM-Card as novel system [Maurer and Scherbakov 1996] deserves some explanations:

HM-Card is a set of tools that enables authors to build powerful interactive multimedia presentations and courseware. "Interactive" means that the system does not just allow the users to choose different paths from time to time, but that fairly complex system-user dialogues can be incorporated, e.g. for checking the level of understanding as required for training applications, hence the term "courseware". "Multimedia" means that HM-Card allows to combine text, graphics, animation, raster images, audio and video clips: HM-Card has a built-in editor for text, graphics and animation and allows to import and integrate other media types (e.g. images and video clips) readily. Above all, HM-Card provides a new paradigm for "navigating" from one multimedia document to another, both with and without the use of so-called "hyperlinks".

HM-Card includes powerful features to help ensure "link consistency" and to allow a modular approach to the design of presentational packages and courseware that assures unprecedented ease in reusing and modifying existing modules.

HM-Card is thus a set of tools designed to create and peruse:

- Personal multimedia information systems;
- Computer supported educational packages ("Courseware", i.e. CAI packages)
- Shells combining other applications into an integrated system with a flexible multimedia user interface;
- Multimedia presentations and demonstrations without or in combination with other WWW material.

All tools necessary to create such applications are included in HM-Card. The preparation of material is done without having to program. Rather, authors simply select suitable media objects, define necessary parameters and place them on the screen - even computer animation and question-answer dialogues can be built this way.

Material created can be structured so that it is easy to maintain, reuse and peruse modules. HM-Card is thus suitable for both personal hypermedia authoring as well as professional multimedia publishing. HM-Card Material can be used "stand- alone" via WWW, and can be fully integrated with other WWW material.

For examples of courseware consult http://www.iicm.edu/hmcard on the Web.

Summarising, HM-Card is the only authoring system for presentation and courseware material that does all of the following:

- includes an editor for vector graphics and animation producing very compact resultant files (a big plus if courseware or presentations are offered via WWW);
- provides the facility to author complex question-answer dialogues without resorting to programming or scripting;
- allows the step-wise and modular production of courseware units;
- supports reuse, maintenancee, customisation and the administration of large databases of courseware fragments;
- provides new navigational techniques that help the user, and provide facilities for automatic link maintenance not found in any other major system except Hyper-G/HyperWave;
- can be used stand-alone or in connection with WWW, i.e. Hyper-G/ HyperWave;
- allows cross-references to other material, creating an arbitrarily large "digital library".

3 Overcoming CAI weaknesses and adding functionality

We have looked at the development of CAI in Section 2 and have diagnosed a number of crucial weaknesses that have not been fully addressed in existing CAI systems. We have indicated that LATE does indeed provide solutions for all aspects mentioned.

Before we discuss how LATE manages to overcome those weaknesses we want to remind the reader that LATE is based on Hyper-G/HyperWave, the first second generation WWW system, see [Maurer 1996]. It should be noted that Hyper-G/HyperWave as WWW system with non-embedded, bidirectional typed links, a global annotation concept and powerful data structuring allows easy customisation of presentation material including such material for educational purposes; and the communicational features of Hyper-G/HyperWave provide the basis for networked cooperation of all players involved in LATE. Thus, some of the weaknesses of traditional CAI systems are immediately removed or at least mitigated by using Hyper-G/HyperWave as basis of LATE. Other important features (like the programming free authoring of "semi-intelligent" question/answer dialogues) are partially taken care of by using concepts of HM Card.

Let us now look at the various issues one by one in some more detail, returning to them in more concrete terms in Section 4.

LATE can be seen as a set of traditional multimedia CAI modules enriched by additional functionality and material. LATE modules can be used for self-study purposes, or by instructors as replacement of traditional lecturing techniques involving e.g. overhead transparencies. Multimedia components include of course animation and audio- and videoclips. This not only assures that explanations can be given in an optimal fashion but that the teacher can be heard and seen from time to time reducing the "impersonality problem" of traditional CAI.

Whenever material is used both for self-study and as basis of orally delivered lectures the amount of (textual) explanation becomes an issue: overhead transparencies - or with LATE their electronic counterpart - should only contain key phrases, the complete explanation given by the lecturer. Contrariwise, self-study material has to be - if the student wishes - complete and selfcontained. For this reason traditional CAI modules are either good for self-study but not for the delivery of lectures (since "frames" are overloaded with details) or are good for the delivery of lectures but not really suited for self-study (since detailed full-sentence explanations are missing). In LATE "frames" are implemented using the cluster concept of Hyper-G/ HyperWave: explanatory graphics and animation come in a cluster together with "full text", "sparse text" and "audio", and depending on user preferences a combination of those will be delivered. Typically, self-study will use "full text" with audio available on request (by activating an icon), while the same material would be used with "sparse text" when used in a lecture room setting. Observe that already here it becomes apparent how the material can be used for multiple purposes: a student may listen to a lecturer who presents the material with "sparse text", but may later review it with "full text" and "audio" preferences.

Another problem with traditional CAI is the amount of guidance offered to students. Strict guidance leads to the "tunnel syndrome" (i.e. the situation that when working thorugh material there is little choice except for following "one linear path"); the ample use of hyperlinks that does provide much "navigational" freedom but is no solution either, since it leads to the "lost in hyperspace syndrome".

In LATE, modules typically allow for a good amount of navigational freedom, each frame e.g. having options to go back to the table of contents (of the whole module or a well-defined part of it), options for "fast forward" and "fast backward" (akin to leafing through the pages of a book) and occasional links for shortcuts, further explanations, etc. However, LATE usually will not provide a plethora of hyperlinks (although such decisions are all up to the authors of the courseware material): rather, LATE allows at any time the use of (and search in) a "background library" whose composition has been set beforehand by defining a certain "scope" within the database.

This is where LATE combines CAI with digital libraries and the unique scoped search facilities available in Hyper-G/HyperWave. Basically, each module is part of the Digital Library available in LATE. This digital library contains CAI modules, other WWW multimedia material, the electronic versions of books and journals, see e.g. [Maurer and Schmaranz 1995], executable programs, etc. Using features of Hyper-G/HyperWave LATE allows to associate with each CAI module a subset of the library that is called "active". Any search initiated by a user will always involve all and only the documents of the active part of the library. To be specific, suppose a CAI module deals with a computer science subject and the user is German but has a working knowledge of English. The "active" part of the library could then be all computer science literature and material available in either English or German, with a dictionary English-German in case some English terms not known to the user will occur.

It must be carefully understood that the student can use the library whenever needed before continuing with the CAI modules at issue, but that this is only one of the ways for students to obtain additional information: communicational tools like bulletin-boards, chatting to other students currently on-line, etc. are also available. We will return to this in Section 4.7 – 4.10.

One of the main points of criticism of traditional CAI is the often limited amount of "interaction" available to students: too often CAI modules degenerate to "page turning in a beautiful multi-media enriched book". LATE, however, provides features for much interactivity:

- students can use the electronic library to "browse and explore" at their leisure;
- they can interact with other students and teachers through electronic means to be explained in detail in Section 4;
- they can activate "simulation modules" where available;
- they can test their knowledge in question/answer dialogues either provided a priori through facilities in HM-Card or available due to questions resolved electronically earlier on; as will be explained in Section 4 students can ask questions that are answered by teachers or tutors immediately ("synchronously") or at some later stage ("asynchronously"): such question/answer dialogues are added by LATE to the underlying CAI module. Thus, CAI modules get "enriched" by additional material over time;
- the fact that LATE is based on the connection oriented protocols of Hyper-G/ HyperWave also opens the possibility for user-tracking and even student modelling, if desired. Note that this feature - one of the strong points of PLATO - is thus resurfacing after years of neglect!

One other main obstacle to the use of CAI in the past has been the effort required to prepare high quality CAI material. This effort is much reduced in LATE for two entirely different reasons:

(i) the authoring of question/answer dialogues requires that authors "guess" what questions will be asked, a tedious if not futile undertaking. Since questions and their answers can be incorporated using LATE at the time the questions are asked this problem all but disappears;
(ii) authoring a high-quality CAI module will always be very time consuming if done from scratch. However, LATE supports the re-use and customization of material existing in the Digital Library to an unprecedented level hence easing the authoring process dramatically. Indeed even "authoring on the fly" (see Section 4.5) becomes a distinct reality.

In addition to above, the communicational features of LATE, and its network environment, make the perusal of CAI modules a process that is very different from the traditional one-person self-study paradigm found in classical CAI. This will be much clearer after Section 4, hence a more detailed discussion is postponed.

Summarizing, LATE provides an open multi-user teaching and learning environment whose flexibility opens new vistas for the whole educational process: from university instruction to distance teaching, from training on demand and training on the job to life-long learning.

4 LATE Modules

4.1 General Description

In this Section we will discuss the various conceptual components of LATE ("modules") in more detail. Note that LATE is a symbiosis of those modules.

As result of implementing the LATE concept a complete LATE software package, a description of how to use it and a number of pilot courseware modules with a documentation of their complete life-cycle would be available. The full implementation of the LATE concept will, however, require a major effort on a pan-European level.

4.2 The CAI Module

LATE allows the creation and use of educational multimedia material based on WWW, including HTML 3.0, PDF and - in particular - HM-Card [Maurer and Scherbakov 1996]. Observe that HM-Card has a built-in "editor" for text (vector) graphics, animation and "semi-intelligent" question/answer dialogues (including "free-text answers", control of cursor movements, etc.), allows private annotations (in addition to the annotation feature of Hyper-G/HyperWave) and flow of control based on student answers.

No matter how CAI modules are created, their textual components are searchable and they can form part of the Digital Library in LATE that can be activated whenever desired. The use of CAI modules can thus be arbitrarily interleaved with consultations of the Digital Library, or with the use of communicational features (see below).

4.3 Modern Lecturing

LATE does not only provide an environment for learning (for self-study alone or in electronically connected groups of students) but also provides invaluable help for the teaching process: a lecturer - rather than using traditional blackboards or overhead transparencies - can use modules from the Digital Library in a lecture (using a video beamer or LCD panel). Note that existing material can be used as is, or can be easily be combined with other and own material: in HM-Card this is due to the modular HM-Data Model [Maurer and Scherbakov 1996] and in Hyper- G/HyperWave it is due to the flexible link paradigm employed [Maurer 1996]. Note further that the cluster concept of Hyper-G/HyperWave allows to use the same kind of graphic material or animation with more or less text interspersed, as already mentioned in Section 3.

Hence, preparing a good lecture using LATE will often require at most as much effort as producing a good set of overhead transparencies, yet in doing so much more is achieved as will be explained in Subsection 4.5: the set of transparencies shown and everything added to them in terms of explanations can be recorded in real-time for later perusal as CAI module, i.e. "Authoring on the Fly" becomes reality.

To support a lecturing process akin to what is ordinarily used an "electronic whiteboard" has to be integrated into LATE.

4.4 Digital Library

Hyper-G/HyperWave has already been used as basis of successful digital library projects in the past. For concrete examples consult [IICM 1996]. Note that the LIBERATION project (sponsored within the Telematics Application Program of the European Commission) is also Hyper-G/HyperWave based and helps in creating a body of material and, most important, information on how to use the material most efficiently.

Digital libraries built on Hyper-G/HyperWave basis as used in LATE go beyond other digital libraries in a number of ways: first, the powerful search engine can be applied to well-defined subsets of the library due to the possibilities to define hierarchical scopes in Hyper-G/HyperWave; second, material can be easily customised by combining existing material with links in the sense of Ted Nelson's "transclusion principle" [Nelson 1987], and third, charging is done via the convenient "at most n users at a time" mechanism; fourth and finally, arbitrary material - including CAI courseware - can be included in the digital library. Thus, the digital libary of LATE can be tied together with other modules of LATE seamlessly.

For the billing issue see [Maurer 1995a], for the digital library component as a whole consult [Lennon and Maurer 1995b].

4.5 Authoring on the Fly

The term "Authoring on the Fly" was first coined in [Maurer 1994]. It is discussed in more detail in [Lennon and Maurer 1995a] and has been taken up successfully by Ottmann et al in [Ottmann and Bacher 1995].

The basic idea is closely related to Section 4.3: a lecturer presents material that has been prepared in a hypermedia system: in our case it would reside within the Digital Library of LATE. This material is now shown to students (using a video beamer or LCD panel) exactly as described in Section 4.3. However, while the lecturer explains the material the lecturer's voice is recorded as digital audio clip, and the lecturer's image as digital video clip. This is stored in the hypermedia system together with the material shown.

Thus, at a later stage, the lecture presented can be revisited: all material shown by the lecturer, including the lecturer's voice and image can be retrieved. Watching such material is very similar to attending a real-life lecture!

As convincing and simple above notion sounds there are a number of details that have to be resolved. We mention only a few as examples to show the complexity of the situation.

(1) Storing a continuous video of the lecturer is very storage intensive. Surprisingly it turns out that it is not even desirable to do so for psychological reasons: students get quite irritated if the face of the lecturer is visible in a window all the time. Thus, students should be allowed to close that window, and a video is not necessary all the time.

(2) It is not clear what the video of the lecturer should show: the face? the whole body including the gestures? what resolution is necessary or desirable? In LATE we propose to give lecturers at each point in time the option to show them: as still picture that is taken once every n-seconds (n a parameter); as full-person video; as face-only video; or not at all. As a matter of fact the option could be decided by a position sensor on the basis of the position of the lecturer at the time the material is presented to make explicit commands unnecessary.
(3) Lecturers do more than just show material and talk: they also show (highlight) certain things, may want to add or sketch something etc. Thus, simple "whiteboard facilities" are required, and the actions on the whiteboard have to be also recorded.
(4) The idea to associate sound- and videoclips with documents may not seem to pose problems, but it does. When a lecturer changes from one "transparency" to another this is often done in mid-sentence. Chopping the sentence into two parts is very problematic since timing delays when retrieving the material can result in strange phenonmena. Thus, synchronisation with the end of sentences, or pauses in the speech are important . . . and difficult to handle, automatically.
(5) When recording a "live" lecture the audio quality that sounds OK in the live setting is not good enough for later perusal: the pauses, "ahems", "ahs" and small mistakes become oddly disturbing. Thus, real "authoring on the fly" is a dream: some editing (at least of the sound track) is always necessary afterwards! This requires the addition of efficient post-editing features into LATE.

Thus, in reality, authoring on the fly is not going to produce very high quality CAI material. However, the production of CAI material in a fashion akin "authoring on the fly" by using the audio- and video component provided by a lecturer is by far the most cost effective way to produce good (maybe not professional quality) courseware. This is one of the principles of LATE: courseware production must be made easy (i.e. not time consuming) or else the implementation of the LATE concept would be likely to have the same fate as earlier CAI undertakings.

4.6 Distance Teaching

The authoring on the fly process described in Section 4.5 does lend itself to online (synchronous) distance teaching in an obvious way: when the lecturer presents material in classroom A with voice and maybe image being digitised to be stored for later use there is no reason why all of this (material shown, voice, image, . . .) is not also transmitted to another room B (at arbitrary distance) where students "attend" the lecture in this way. Clearly, students should have the possibility for simple feedback ("slow down", "please present an example") or arbitrary other more complex feedback like questions that are brought to the attention of the lecturer and are answered immediately, with the question/answer dialogues potentially incorporated into the material (see Section 4.7). This mode of distance teaching is not recommended to be fully supported by LATE for three reasons: (i) it is not ideal for distance students (they cannot consult the Digital Library or communicate with other persons inbetween without loosing track of the main presentation); (ii) the process is technically complicated due to the need to retain full syncronisation and (iii) experiments show that the distant students feel disadvantaged (even if it is not clear why) in this case.

Rather, LATE will fully support a slight variation whose acceptability by students is much better:

(1) The lecturer prepares CAI material (potentially "On the Fly" as described in Section 4.5 with some post-editing).
(2) This material is stored in a WWW hypermedia system and can now be retrieved by anyone, including distance students (synchronisation and bandwidth do not play such a role now).
(3) Students working through the material can consult the Digital Library or use communicational facilities for help (see Section 4.8 - 4.10), or they can ask questions: depending on whether a lecturer/tutor is online or not such questions are answered immediately, or else at some later stage. And the question/answer dialogues become part of the course material: how this is done is discussed in more detail in the following section 4.7.

4.7 Question/Answer Dialogues

It is important to distinguish two completely different types of questions:

(a) questions asked by the system (i.e. questions built into the courseware a priori);
(b) questions asked by students (where the system is supposed to provide the answer).

Let us first analyze case (a). The challenge here is (i) that authors of courseware have to come up with questions of the right level of difficulty without often knowing their audience, and (ii) that the answers of students have to be analyzed and categorized as wrong (better: wrong because of such and such), as partially correct (better: additional feedback what is wrong or missing) or as correct.

The development of "intelligent" question analysis modules is difficult. Such modules should "realise" that "this is a red broken circle" and "circle of dots of colour orange" may well be both correct answers to a particular question, and that the answer "Aukland" to "What is the largest city of New Zealand?" is certainly better than "Wellington" (despite the fact that the correct spelling is "Auckland"), that "Canberra" would still be worse than "Wellington", but "Paris" would probably indicate a joke or unwillingness to cooperate. HM-Card offers rich facilities for fairly decent answer analysis yet has its limitations, as would be expected. Bottom line is that questions asked by the system have to be formulated in a way that answers can be analyzed properly and should mainly be used for assessing the level of understanding of students. The outcome of such a question/answer dialogue might be the recommendation to work through some part again, to consider looking at some other auxiliary material or (most of the time) some kind of encouragment to continue. Note that question/answer dialogues have been studied exhaustively in traditional CAI systems with only moderately successful solutions. A limited number of such simple dialogues (involving graphical elements like "Assemble the machinery X from the parts A,B,C,D,E,F,G showing the right order and by dragging the parts to the correct location") is recommended for modern LATE courseware - and tools to support such dialogues are provided as part of HM-Card.

Let us now turn to analyze case (b) where students ask questions. In LATE authors need not guess when students might ask which question. Rather, a student may ask any question at any time. Questions can be worded by students in three ways:
(i) formal,
(ii) textual,
(iii) by voice.

(i) A question is asked in a formal way by dragging a question mark icon to a certain place on the screen. This means "I don't understand this part of the screen" - i.e. this formula, diagram, animation, etc. The lecturer/tutor answers this question using arbitrary multimedia technology (text, drawings, voice, video, ...) immediately (if online and if the answer is "easy") or later (with an email to the student "here is the answer to your question concerning ...") (if nobody is online or if the answer requires some preparation). In both cases, the position of the question mark and the full answer is stored. Thus, if a different student asks the same question at some other stage (by dragging a question mark to a nearby position) the pre-recorded answer will be given.
(ii) Students may ask arbitrary textual answers concerning a particular "frame" (state of the screen) by typing the question. The answer process is the same as in (i). The obvious difficulty now is that LATE will be hard-pressed to determine if another similar question concerning the same screen is indeed similar enough to warrant the same answer. LATE refuses to do so. Rather, if questions have been asked concerning some frame LATE shows an icon. A student who considers asking a question clicks at this icon and obtains a list of the first two lines of all questions that have been asked about this frame before: it is up to the s t u d e n t (not LATE) to decide whether one of the previous questions is a close enough match to what the student wants to ask. If yes: fine, a click reveals the answer; if no: the student poses a new (textual) question and will receive the answer at some stage.
(iii) Students can also ask questions by voice. Their digitized audio question is stored, lecturers/tutors answer as in (ii), and rather than displaying the first lines of textual questions the voice-stated questions can be retrieved by students who are about to ask questions. We realize that this process is cumbersome but we do not have a better solution and believe anyway that any frame that attracts too many student questions has to be redesigned: a large number of questions shows that the explanations are inadequate.

Summarizing, the use of CAI modules as described improves them over time as they are enriched by more and more question/answer dialogues. If frames end up with too many questions this is a clear indication that they need improvments. The system provided by LATE thus leads to continous improvements: the same original CAI module may develop in completely different directions in different student environments!

This leads to the fascinationg idea that a "standard course" by an international authority on topic x may develop into courses a,b,c, ... suitable for entirely different audiences. We see that LATE will produce courses where the authors might be acknowledged as follows: "This course is based on the standard course x by famous Professor y and has been extended for students interested in a by instructor b". LATE can thus lead to a new way of "collaborative authoring"! With the billing and customization features proposed in LATE this does not violate any copyrights and does not require new laws: "old" and "new" material is interleaved, but the billing is done a‘ la Nelson's transclusion [Nelson 1987].

4.8 Online Help

LATE will have an Online Help facility that consists of two parts
(i) subject related help;
(ii) system related help.

Subject related help is connected with the question/answer dialogues mentioned in 4.7: at certain times tutors or lecturers are online ("electronic offline hours") and will answer subject related questions. Some of the material (if judged suitable by tutor/lecturer) is added to the courseware available, enriching the material as described in 4.7.

Online Help facilities are also used by students to send exercises and results of tests, with feedback provided automatically in some cases (multiple choice questions, answers to exercise problems) or by tutors/teachers. Selftests and tests can also be administered via LATE.

System related help consists of FAQ's and personalized help (the latter where suitable expanding the FAQ's) to help users master LATE.

4.9 Asynchronous Cooperation

LATE provides access to newsgroups and bulletin boards for discussions among students, or between students and teachers, as one would expect.

However, LATE goes much beyond this by offering structured discussions. Basic versions thereof are available in LATE since they are available in Hyper-G/HyperWave: any subject can be "annotated" by students/readers, annotations are marked as such and can - in turn - be annotated, allowing a "threaded discussion".

However, LATE also allows to exploit the concept of typed links to show a graphical presentation of the structure of the discussion along the lines of Conklin's gIBIS [Conklin and Begeman 1987]. More specifically, after a "thesis" has been stated in LATE, contributions can be categorized as "supporting argument", "supporting example", "counter example", "generalization", "question", etc. And a graphical "map" will show that a particular thesis has led (so far) to 5 supporting arguments, 3 supporting examples, 6 counter examples, etc., and contributions in the various categories can be browsed systematically.

Asynchronous discussions can be carried out identified, anonymous or semi-anonymous (level 3 in [Flinn and Maurer 1995]) and are supported by voting mechanisms in LATE.

Asynchronous cooperation in LATE goes beyond discussions: it supports joint development of documents including version control and version comparison.

4.10 Synchronous Cooperation

LATE supports chat facilities as one would expect. In contrast to other systems LATE allows to identify those concurrent users working in a certain area (scope).

Thus, a student in advanced biology will typically initiate chat actions only with students currently working on material in advanced biology rather than "bothering" all students online, even those currently occupied with entirely different matters.

LATE will also include facilities for (synchronous) audio- and video conferences with facilities to handle different bandwidths: the video conference may e.g. reduce to showing a static image and voices in low band width environments. Multiperson synchronous conferences not only pose formidable technical problems, they also requrie the study of new interfaces. LATE must also include a whiteboard for synchronous cooperation (shared workspace), drawing on efforts in CSCW.

5 Summary

The combination of modules described above in one system LATE would provide the most comprehensive systems for using computers for learning and teaching ever designed.

The implementation of LATE based on the advanced WWW system Hyper-G/ HyperWave and the multimedia system HM-Card, both developed in Europe, is possible today. Indeed, many parts have been implemented in experimental fashion by various research groups. However, the coherent integration and development of missing "bridges" and subcomponents is still a major task and will only be possible under the stewartship of one strong group that coordinates and integrates efforts, and if a substantial amount of funding is provided.

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