Architecture of Web-Based Training and Education System

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Abstract:

We describe briefly a set of experiments using Web technologies in a variety of education and training scenarios. We deduce from our and others' experiences a set of requirements for Web-based education and training systems which we use in the design of WebWisdom, whose architecture and capabilities are described. We also use feedback from general experiments with electronic collaboration systems, as we expect these to be critical in the next generation of electronic teaching and learning tools. WebWisdom integrates a database core with public key-based security, collaboration, multimedia streaming delivery, online computer laboratories, audio-video conferencing, legacy and JavaBean based authoring with tools for assessment, administration and searching.

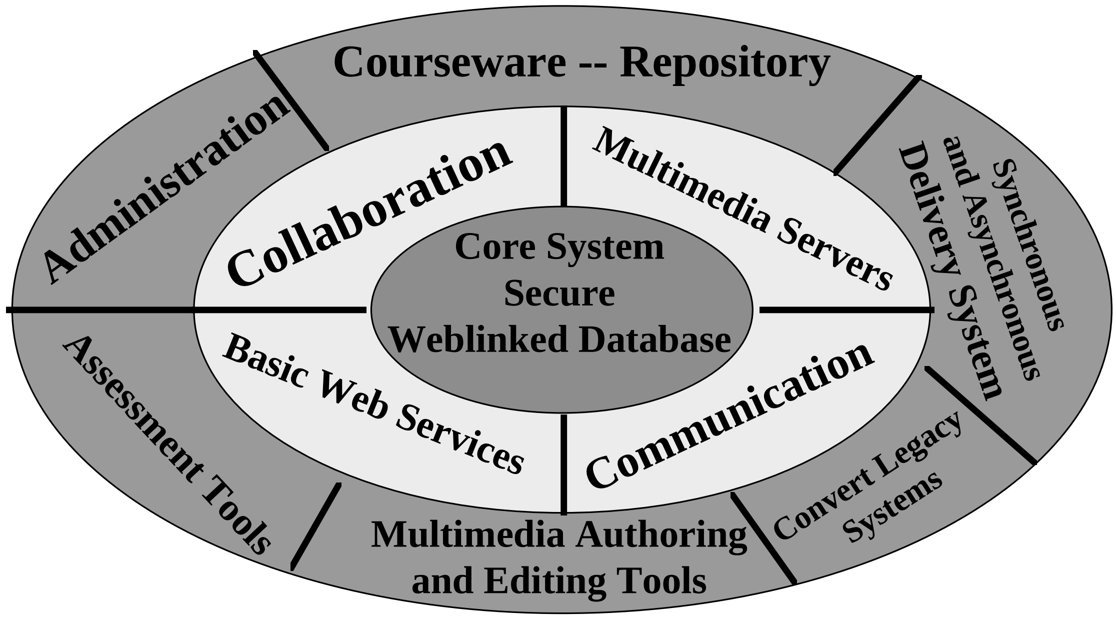
Our experience comes from K-12 area where the Living SchoolBook project used ATM connections to three Central New York schools; undergraduate teaching in the Physics department of science for non-science majors; and graduate teaching of computer science including courses taught remotely in China. We also learn from the design of interfaces for disabled children where assessment tools are a particular focus. Industrial training experience comes from working with a well-known company offering both CD-ROM and Web based foreign-language instruction. We note that much of our understanding comes from outside HPCC, which is to be expected, since I am a teacher of both general physics and computer science as well as a researcher in HPCC.

Further education must be affordable and indeed become less and not more expensive when electronic support is increased. Thus it seems critical that the design of WebWisdom be careful to incorporate the pervasive Web technology that is emerging. However, as these ideas are still evolving rapidly, it is essential to design a modular system with as loose a coupling as possible among components.

WebWisdom Prototype: **http://www.npac.syr.edu/users/gcf/wisdom/help/**

Commercially Supported Products: **http://www.webwisdom.com**

The Virtual University: **http://www.webwisdom.org**



WebWisdom Education and Training System

1: Introduction

Many organizations have used the Web very successfully as a tool to enhance education and training. Indeed although computers have been promoted in this area for many years, their impact (especially in the critical K-12 arena) has currently been modest. There is good reason to believe that the Web will change this and its pervasive use in education can lead to significantly improved learning environments with substantially lower cost. In this article, we will not pursue the important social and business issues implied by this hypothesis and indeed will not try to quantify or justify the increasing use of the Web in education. Rather we will try to design a Web infrastructure for education that we term WebWisdom. The proposed design is shown above in the figure, and in this paper we will describe how we arrived at this architecture based on the study of a set of experiments by NPAC and others on Web-based education and training. These motivating projects are described in Section 3, while we summarize technology design in Section 4, and general issues in Section 5. In the following Section 2, we describe the general structure of WebWisdom, which will serve as a backdrop for section 3 and get expanded in section 4.

2: Overview of WebWisdom

Our proposed layered design of WebWisdom includes a secure database at its core on top of which are built a set of services including audio and video servers; basic Web servers and a collaboration subsystem which is heart of both asynchronous and synchronous delivery. This has a set of basic collaboration capabilities including chat, audio-videoconferencing, whiteboard and shared applications. The communication system supports the worldwide delivery and includes support for distributed databases to get high performance with, for instance, core courseware replicated on delivery machines with CD-ROM’s or other such mechanisms. The top layer of

WebWisdom consists of education and training specific capabilities that customize and extend the generic middle-layer services. Besides standard curricular material, one must support 3D worlds and virtual laboratories for programming and experimental science. Note that assessment relies on a database at the heart of WebWisdom, which logs synchronous delivery of curricula and records interaction of students with courseware and tools. Authoring and editing includes audio, video, and Java applet based animations as well as basic text (HTML) material. Conversion of Legacy systems includes putting Persuasion, Framemaker, PowerPoint, etc. on the Web. The delivery system is based on customized shared browser windows for curricula together with more generic collaboration capabilities; e.g. audio-videoconferencing is used by students and teachers for traditional voice interactions. The collaboration subsystem must support multiple rooms and many groups of users. WebWisdom is to be used by virtual universities offering *ab initio* or continuing education or by not-for-profit or commercial organizations with K-12 curricula augmenting home or traditional education. We do not believe that there is any compelling consensus as to the "best" or "better" modes of learning in the emerging electronic virtual classroom. Rather, WebWisdom must support a broad range of learning styles and, in particular, both asynchronous and synchronous interactions between teachers and students. In fact most historically successful education systems mix (albeit to different degrees) both face to face (synchronous) and offline (asynchronous) interactions. We do assume that a major reason for the attractiveness of the Web is its interactivity and that exploratory learning and its support will be very important.

The productivity of Web technology is partly due to its high-level application interface and partly to the immense amount of available interoperable software that is compatible with universal Web interfaces which are reusable between fields. WebWisdom must be designed to use, wherever possible, capabilities developed outside the education arena. For example, Web-linked database capability is being developed for the large enterprise Intranet market; multimedia servers for the electronic information and entertainment industry; and authoring tools for the general desktop (or what I call WebTop) publishing and productivity market. Most intriguing to us is the area of collaboration where we must support electronically the student, teacher and teacher assistant interactions. Millions of people are forming electronic societies with such sites as www.talkcity.com, www.mirabilis.com, www.worldkids.net, www.geocities.com, www.parentsoup.com building on the success of chat rooms (where America Online alone has 14,000) and Usenet news groups for both synchronous (e.g. chat) and asynchronous (e.g. mail) interactions. There is a popular description of this phenomenon in the May 5,1997 issue of Business Week. These sites are experimenting with different interaction mechanisms and being used for a variety of purposes and we believe that it is reasonable to expect to use these pervasive approaches as the basis of electronic collaboration for education. An interesting start-up (www.centra.com) came out of Lotus Notes and has a similar vision to WebWisdom with a mix of collaboration and Intranet technologies for corporate training. As always, education will require enhancement and customization but, for instance, the use of a broad-based technology core will allow the K-12 area to build electronic curricula which can naturally involve parents and allow children to continue their involvement at home as well as at school.

The above discussion implicitly emphasizes that this paper inevitably strays from a pure HPCC focus. However as detailed in section 3.6, HPCC is relevant and incorporated into our discussion in several ways. These include application of WebWisdom to electronic HPCC curricula such as computational science; use of high speed networking for digital video resources; incorporation of results of HPCC simulations into science curricula. Further the concepts in WebWisdom are very relevant to distributed HPCC consulting and training—especially in today's era of the distributed NSF and other federal high performance computing centers.

The WebWisdom design tries to take advantage of the "best of the Web" and, in particular, we are currently surveying an emerging crop of technologies for the support of databases and collaboration. However, as the Web is still evolving very fast, it is essential to design a modular system with as loose a coupling as possible among components. In this way, we can be best positioned to take advantage of new developments. In general, this paper will not survey the basic Web technologies but rather focus on their application to education.

3:Some Web based Education and Training Activities

3.1 K-12 Arena

Here my experience comes from the Living SchoolBook project (http://lsb.syr.edu) that was funded by New York State to explore new curriculum opportunities opened by high-speed networking. This involved ATM linkage of three Central New York schools to NPAC and other sites via NYNET. Here NPAC developed advanced curricula resources, and the University's School of Education provided key linkage with teachers and students, while NYNEX donated the ATM link. This project was technically very successful, as we were able to develop and deploy (in a limited fashion) three important applications:

- Web-linked database search engine for educational material supplied traditionally in CD-ROM format. This was, not surprisingly, attractive to teachers and we are working with them to improve the interface.

- Text-indexed video-on-demand server. This was one of few applications that demanded the high-performance link and was used for both commercial videos and amateur material from students and teachers. The latter were made to record local landmarks and interviews with visitors. Here we found it hard to freely use material due to copyright restrictions. We found it particularly easy to use close-captioned tapes, as we can simultaneously read time stamped captions into a database as we digitize the tape. However, the interesting local material needed the database indexing to be added in a less automatic fashion.

- Web-based Geographical Information System (GIS) using a variant of VRML to display the terrain and allowing one an attractive intuitive interface to spatial data from either public sources or at teacher/student-prepared sites. This shows that one can use and WebWisdom must support more general user interfaces than traditional text. The raw data for this project are stored in an object (not relational) database and these more general data types must be supported in the core WebWisdom database. Both Oracle and Informix (linked to Illustra with their universal server) are possible commercial sources of combined object and relational storage. Our award winning VRML2 interface to the Visible Human data (http://www.npac.syr.edu/projects/3Dvisiblehuman/) needs similar support. Other interfaces one might need to support include sophisticated visualization front-ends such as the CAVE.

Most of the deployed applications were correctly curriculum-based and not technology-based and a good examples of this is our original Kidsweb resource (http://www.npac.syr.edu/textbook/kidsweb) which for last two years has been NPAC's most popular site. This is a selection of Web sites in several areas while the schools have made interesting focused group projects such as the Cyberzoo resource.

We have found it hard to capitalize on this success, because so few schools have the necessary network infrastructure to use such high bandwidth. We found an interesting technology transfer statistic. Namely we started with a reasonably representative (random) group of 20 teachers and, of these, about half really took off and now provide a source of Internet/Web expertise in their schools. This illustrates that such projects can help to retrain our educators.

3.2 Undergraduate Teaching

Here we have successfully worked with the Syracuse Physics department (http://www.phy.syr.edu/courses/modsim.html) on first integrating basic Web resources, then Java applets, and now Tango collaboration technology into their introductory course PHY105/106 "Science for the 21st Century". This course for non-science majors sustains great student interest (over 250 enrolled each semester) as it is organized into stimulating modules (such as Mind and Machine or the Search for Extraterrestrial Intelligence) and the Web allows material to be very topical and up to date. Further using the Web in the class teaches them skills of general value. This and several other such physics education projects (for instance TIPTOP) are described in the February 1997 special issue of IJMPC (International Journal of Modern Physics C http://www.wspc.com.sg/journals/ijmpc/81/ijmpc81.html). Here one needs both Java applets executing simplified simulations and visualizations of more sophisticated server side programs that could run on HPCC resources. The latter need to be shared (perhaps with collaboration technology) if scalable delivery of realistic simulations is to be supported. We have also learned how to collaboratize simulation applets with a teacher manipulating a master system and interacting with students responding to questions. This requires quite complex session management to allow control of simulation to be safely shared between several users. Example applets illustrate basic mathematics (notion of a vector cross product) and elementary mechanics (illustration of the motion of springs or planets moving under a gravitational force). In the gravity example, the teacher can start a simulation, change the nature of gravity and ask students what this implies. Students respond by drawing on the simulation display which doubles as a white board. The correctness of their ideas is then illustrated by resuming the simulation, while the teacher ponders the variety of predicted orbits given to her by the students. It is important to understand not only if sharing such simulations is educationally important but also what type of teaching could be impacted by such approaches that offer new opportunities compared to conventional methods.

The above discussion illustrates the essential ideas behind collaboration systems such as Tango from NPAC or Habanero from NCSA. These are set up as a Web server that controls multiple sessions. A session is typically one or more applications such as a chat room or a delivered Web lecture (implemented as some form of shared HTML page), or as above a more sophisticated simulation. In each case, the application is replicated on multiple clients and the server ensures that the state of each application is consistent between each client. For instance, it ensures planets are in the same place in the shared gravity applet and that the browsers are accessing the same page on each client in the shared lecture. Note that one replicates an application and not the displays of a single application as in some other collaboration approaches.

3.3 Graduate and Continuing Education

This area has much in common with training offered in corporations and to that supplied to users of HPCC supercomputer centers. Distinguishing characteristics are relatively focused advanced curricula and typically highly motivated students. It is likely that asynchronous training such as that very successfully used by Cornell in their Virtual Workshop, is particularly suitable (http://www.tc.cornell.edu/Edu/VW/modules.html). However synchronous delivery of all or part of the material is also important. Here we see the need for curricula to exist in several forms -- highlights (bullets in presentations) as typically used in lectures; exploratory detailed material as needed by asynchronous learners; and background pedagogical resource for student reference. Very little material today has this multi-level structure although the Virtual Workshop does offer a partial hierarchical structure. Correspondingly synchronous systems such as our prototype WebWisdom (http://www.npac.syr.edu/users/gcf/wisdom/help/) offer "notes" capability (as available in commercial presentation software) or the availability of "voice- or video-over" (typically in Real Audio Web format as pioneered at http://renoir.csc.ncsu.edu/RTCPP/index.html) to add detail to the highlights. I believe more experimentation is needed to find the optimal ways of supporting the different delivery mechanisms with both visually clear highlights and additional detailed asynchronous resources.

In teaching computer science, one needs to incorporate programming laboratories both into the actual delivery of the course and homework. This was emphasized to us when teaching Java, JavaScript and VRML where this is essentially automatic due to the natural Web integration of the languages. We found the ability to go through exemplar codes and illustrate their execution in real-time to be an invaluable aid to teaching. Again students obviously prefer to learn such languages where success is not measured by dull text output -- printf("Hello World") -- but rather by the production of an interactive Web pages that can be shared with their peers. This motivated us to develop virtual programming laboratories (VPL) for both HPF and MPI (http://www.npac.syr.edu/projects/VPL/) and PERL (http://www.npac.syr.edu/users/gcf/perlvpl/). These are successful but still need more experimentation; our latest VPL is now available with integrated Java visualization of data and performance visualization. Such capability should be included in the design of WebWisdom and is incorporated through the notes feature of our current prototype.

We have linked the current WebWisdom to the collaborative system Tango and shown how a complex JavaScript teacher interface can be linked to a simpler student interface which has just the selected material and not the full capability of easily selecting material to teach. This ability to support multiple views of the same basic application is an important feature of collaborative systems. This set-up (teacher and student both with their own independent computers) is particularly helpful in teaching programming, as it avoids visibility problems that occur if you try to go through programs which cannot easily fit on an overhead with font sizes that display in a classroom with a single display. Further we note that our educational applications have needed a link of Tango to C++ (3D GIS), Java (physics simulations) and HTML and JavaScript (Web delivery). Such a multilingual interface appears to be a critical feature of collaboration systems. Discussions of the use of Tango and the NCSA project Habanero to share simulations can be found in the papers collected in the "Java for Computational Science and Engineering" resource.

In delivering lectures and courses, I have found that, when using transparencies and overhead projectors, I made up talks dynamically by selecting material from different foilsets that were produced on multiple computers in different fashions. It is not clear if the volume vendors will support the necessary authoring but currently I find it necessary to mix Persuasion, PowerPoint, Framemaker, LaTeX, computer screendumps and HTML pages in a given presentation. This integration of (legacy) systems is fully supported in the current WebWisdom and in the future we will improve the user interface with a Java Applet to allow the user to define graphically the "play-list" of selected material. We also noted this type of capability is useful for storage and selection of other image collections such as those of family photographs (http://www.npac.syr.edu/users/gcf/familyphotos/). A minor feature we added for remote instruction is the capability of highlighting the part of the presentation page on which the instructor is focusing. Currently this is implemented rather crudely with JavaScript but we are developing a new JavaBean based system. Here each foil is viewed as a Java object (whose classes define text and images on a Web foil) which is authored and viewed by a whiteboard that is in the JavaBean language a "custom property editor". The play-list discussed above becomes the graphical "BeanBox" interface to link the JavaBeans together and form a complete "application" which in this case is a lecture! Another approach to Web authoring is the system *Itinerary*, which is offered by the start-up http://www.contigo.com.

We have successfully used our HPCC and Web course material to teach across the globe (http://www.npac.syr.edu/projects/icpse_spring96) to students in China. This was inevitably asynchronous with a mirror site supplying material locally and email/FTP interactions between NPAC and Harbin Institute of Technology. This succeeded due to student commitment and the use of faculty at both NPAC and Harbin. We also found that, although English is universally learnt in China, it would have been very useful to have the base material in Chinese. Thus Harbin has translated key material (such as HPF and MPI definitions) and some of my curricular material into Chinese HTML (http://www.npac.syr.edu/projects/pcrc/cpswt/index.htm). This has been distributed freely on 1,200 CD-ROM's, which is an example of using the Internet and Web technology to broadly disseminate the latest technologies. We will apply these ideas this fall to teach faculty and students at selected historically black universities and colleges. In particular, we will use a mix of distance and on-site teaching in the course on introductory Web technologies for undergraduates at Jackson State. This exciting project is sponsored by the CEWES center of the DoD modernization program.

As a final example in this area, we turn to the novel Language Connect University (http://www.syrlang.com/) which has recently been started by Syracuse Language Systems (SLS), which is a leading PC vendor of language instruction. This work uses a core database technology (Web-linked Oracle plus PL/SQL) and features rich administrative functions built on top of this. An NPAC spin-off *Translet* designed and built this subsystem, whose general structure we intend to follow in WebWisdom. We can learn from SLS some interesting business pointers for future virtual universities. SLS will be able offer training (is this different from education for mature students?) at substantially lower cost than traditional universities. However, their strategy is to pursue corporate training opportunities where there is a large market and the necessary accreditation is an easier process without government hurdles.

3.4 The Virtual University

In general, we suggest that the continuing and graduate education areas are the most promising initial focus of advanced technology initiatives, because the student motivation is very high and we can test and develop ideas that can then be applied at the more challenging K-12 and undergraduate levels. We believe that one should and must price the distance education offerings below that of traditional universities. The ability to reach more students and use less physical infrastructure must reduce the delivery and course preparation cost. Actually, per course the cost of preparation will increase as the sophistication and quality of material is higher, but the cost per student should decrease. The cost of mentoring should be comparable to other approaches. In our experiments, we will try to monitor carefully these different costs and so establish the basic economics of the Virtual University. We note that many prestigious products of national reputation have lower-cost companions. We suggest that universities should do this with a full-tuition onsite education, accompanied by distance offerings of the same material at a lower price. We call this the "Courtyard by Elitist University" strategy to mimic the Marriot Hotel chain's lower-cost companion system (Courtyard by Marriot). NPAC is currently setting up its WebWisdom.org virtual university, which will offer courses that have similar curricular structure to regular Syracuse University offerings but at substantially lower cost. It is our responsibility to convince students, employers and universities that the graduates with certificates from WebWisdom.org have learned as much as those students using more conventional teaching. Note that we use the term certificate, as we expect it will be hard to persuade Universities to give regular credit for such courses until their effectiveness and business model are better understood. WebWisdom.org intends to offer the necessary software, hardware and personnel support to any entity wishing to offer distance education. Initial contacts with potential students suggests that they would only be able to take non-credit courses if the cost was low because otherwise many employers will not reimburse part or all of the course costs.

The database logging of sessions should include analysis of time spent by each student either synchronously or asynchronously on the course pages, and this information can be included with the grade as part of "certificate of performance". Of course, one cannot guarantee that a student is actually understanding or even looking at a Web page displayed on his computer. Thus traditional homework and quizzes are necessary to back up the session data. Here, our Web based computer laboratories are important in supporting the preparation and reporting of homework by remote students.

3.5 Special Education

A very innovative project led by medical doctor David Warner and biophysics Professor Ed Lipson is developing Web interfaces and customized material for physically and mentally disabled individuals. (http://www.pulsar.org) We can view this as bringing the special education requirements to the design of WebWisdom. Note that the Web offers tremendous opportunity to produce affordable and higher-level capabilities for the disabled. Thus it provides a universal set of high-functionality user interfaces to which we can link a wide variety of human input devices.

A quadriplegic Eyal Sherman is able to browse the Web using either optical detection of his facial muscle movements or the output of electrical sensors detecting muscle movement. We feed these general sensors through filters and use them to control Java and JavaScript event handlers. As long as the authoring system can produce relatively uniform interface, we can give Eyal and similarly severely disabled individuals comparable learning opportunities to those of able-bodied students. Note that currently WebWisdom uses Perl scripts to customize the same base material for a variety of uses. We see that this "indirection" between raw curriculum and presented pages should be continued and will be invaluable in producing output customized to the needs of the particular viewer. Whereas this is currently done as a batch step, we expect to switch (or offer as an alternative) interactive real time generation of customized front ends from raw curricula stored in the Web-linked database that we propose as the core of our next generation WebWisdom.

A WebWisdom feature pioneered in this project is the use of a database backend for assessment where this is natural from both an educational and medical point of view. This illustrates that the WebWisdom architecture can be extended to support areas such as home healthcare or more general medical database applications. The SmartDesk projects of Warner and student Myeongjin Lee is developing a set of interactive Web resources aimed at helping teach handicapped individuals in an attractive game-like environment. This originally used Macromedia Shockwave technology, which is being replaced by Java which although currently slower in some cases, is obviously more accessible. This project is focusing especially on recording the students' actions (such as how many correct and incorrect mouse clicks) for new approaches to assessment.

3.6 Relevance of HPCC

Most large HPCC projects have a substantial education outreach and training component and it is important to realize that many activities in this area are in fact sometimes only indirectly related to HPCC. This is perhaps inevitable, as HPCC is a relatively small part of computer science and outreach must not only explain all parts of computer technology but also leverage delivery systems built for the largest markets.

The technology described in this paper can be used not only in University teaching but also by the (parallel computing) training and consulting functions of the large DoD, DoE, NSF and other HPCC centers. In particular material developed for graduate education is naturally at about the same level as that needed for training. For instance one might do training in HPF and MPI, but education in programming paradigms using MPI and HPF as examples. This suggests that some of the certificate ideas of section 3.4 could be usefully used as a way of integrating a broad computational science education into HPCC center training. For instance, whereas you can persuade a user to take MPI training, they probably also need expertise in modern parallel algorithms, and yet such material is rarely part of a supercomputer center training activity. We once suggested scalable certificates so that one could structure material starting with a short one-day event, through a two-week session, a one-semester course, a few-semester course certificate and ultimately a masters which is typically around 12 semester course equivalents. The hierarchical Web information systems naturally support this concept, allowing a suite of offerings to be tailored to suit the need of a broad range of users whose education can be advanced in an incremental but integrated fashion. We have started this with a three-semester course equivalent "Professional Certificate in Internet Applications Development" offered in two 3-hour sessions per week over a five month period. This shares material with 3- to 5-day tutorials and courses that are taken by undergraduate and graduate students in the regular Syracuse University curricula.

Our work with China brought out possible interesting differences between Chinese and U.S. University needs. In China, we taught (and translated into Chinese on our CD-ROM) an integrated "advanced computing science" curriculum including both Web and HPCC concepts. In the USA, these topics are at different levels of maturity and the integration is not so useful. However in emerging countries, the integrated curriculum -- called *Internetics* by my collaborator Xiaoming Li of Harbin Institute of Technology and Peking University -- is very appropriate.

As well as education about HPCC, another major concept is using WebWisdom technologies to deliver large-scale simulations to a broad audience. Here we assume that it is possible for the non-specialist to understand a particular field (say environmental engineering) from a suitable version of a simulation in that field. This could be a stripped-down Java applet capturing the "essence" of the science; this is essentially the idea described for the shared physics applets of section 3.2. Alternatively we might use the full simulation running on a backend MPP. It is not realistic (scalable) to imagine each student running his or her own simulation. Rather the results of one simulation need to be shared in some way. This could use Habanero or Tango to distribute the real-time simulation with mentors on one or more "master" systems describing or annotating the material. Alternatively, one can build digital video or slide-shows from successive displays of the simulation, which can be viewed off-line. This is an interesting variant of the traditional analog video display of a simulation, as the user can interactively change the course of action. There are several well-known interactive PC games built around this concept of dynamic digital video.

4: Functionality and Technology of WebWisdom

Here we integrate the above discussion using a functionality and technology focus, rather than the individual applications described above. We will describe our proposed future system and not the current capability. The latter essentially consists of separate systems, which illustrate all the essential features but are not integrated. Further we intend to replace current ad-hoc implementation by more powerful technologies. For instance, our current delivery system is built using Perl accessing text files but, as we have grown from a handful to over 400 foilsets over 2 years, it is clear that this must be replaced by database storage. The central database is used to store not only this curricular material, but also administrative information and student homeworks, and optionally to log sessions. In addition to grades based on conventional quizzes and projects, the logging allows WebWisdom to certify the amount of time spent by each student in both synchronous and asynchronous sessions. Logging of student-mentor sessions will also be helpful in preparing recommendations and grading. Currently our database systems log electronic mail and chat sessions, and we are generalizing this concept. Course material can either be conventional Web pages or JavaBean or HTML displays generated dynamically from the database material. The user can customize these displays with templates. WebWisdom will adopt modern Web security technology and, in particular, probably use public key authentication as its basic security mechanism. Optionally sessions and fixed storage will use secret key technology to protect confidentiality of material.

The Tango collaboration system provides an interactive multi-room electronic learning center which links teachers, mentors and students with traditional collaborative tools -- chatroom, audio-video conferencing and shared white-board. Shared-curriculum viewers provide the basic support for synchronous and asynchronous learning of either specialized or general Web pages. Each virtual classroom can be configured with different capabilities and different access privileges by the WebWisdom administrator. The core database in Tango stores all the registration information for participants allowing many secure but dynamic electronic societies to use each instance of WebWisdom. One can support both Tango and the database with one or more Web servers, and so the implementation can be scaled to provide good performance for large user communities. Currently, WebWisdom uses conventional HTTP servers with small custom Java-server enhancements. We will migrate this to commercial Java servers when this appears appropriate. General client side applications can be linked by Tango into WebWisdom and this allows customized systems for teaching in different disciplines. One optional specialized application is a shared Geographical Information System supporting three-dimensional virtual field trips, which we described in section 3.1. WebWisdom can be configured with an advanced digital video server that supports either high resolution MPEG or low bit rate H263 delivery (MPEG and H263 are standard video compression schemes). The video server is supported by the core Web-linked database which stores metadata and textual indexing material that can come from closed-captions or user annotations. The compressed video is stored directly on the server file system, and one can start the video at any point located from a search of the text index to the video material. The WebWisdom video subsystem comes with a Web-based administrative asset management system. The video is delivered by a high performance distributed set of servers using multicast technology.

WebWisdom supports authoring with conventional presentation graphics such as PowerPoint, Persuasion or Framemaker and offers consistent "legacy" conversion tools that export such presentations to the Web. New material is preferably developed as a set of JavaBeans, supported by the object oriented whiteboard supplied with WebWisdom. These support distributed highlighting of material within the individual foils and so enables the instructor to indicate the focus of attention at remote sites. Such customized curricula can be intermixed with conventional HTML, and a Java tool allows one to build up new lectures interactively as mixtures of existing "basic" presentations. The curriculum material is stored either directly or indirectly (URL or pointer to video files) in the core database.

5: Conclusions

In Sec. 3, we described several educational initiatives with an emphasis on extracting lessons that can be used in the design of the next generation delivery, authoring and storage system WebWisdom shown in the figure. We collected some technical implications in Sec. 4. The lessons are not conclusive and, in particular, we intend to further refine the requirements by studying the needs of both the new NSF Alliances and the DoD Modernization centers. However, we do believe that there is enough education experience, and further that Web technologies are well enough understood that one can start the major effort involved in implementing the system shown in figure 1. We are currently refining the design and exploring federal, state and commercial funding opportunities. We expect that a good and relatively complete prototype of the integrated system described in section 4 will be available by the end of 1997.