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# Purdue-On-Line: A Facility and Distributed Learning Framework to Develop and Deliver Internet based Education[1]

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1. This effort is supported in part by Purdue University, Intel, AT&T, IBM, Department of Computer Sciences and Schools of Sciences and Veterinary Medicine.
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## 1.0 Project Overview

We have started a distributed learning research and development effort to design technology solutions and methods which support collaborative learning *any time* and *any place*. This project is referred throughout as **Purdue-On-Line (POL)** The main research goal is to develop and integrate *telelearning* technologies with supporting services needed to enable existing courses, to design and deliver "on-line courses" and to meet the growing demand for distance education. Our first target areas include a) freshman education and specifically courses that involve large number of students currently taught in a lecture-recitation mode and b) professional programs in software engineering, computational finance, and veterinary medicine. Following we summarize the goals, activities, and challenges of the POL project.

**What is the future scenario for a University?** We are witnessing the start of a revolution in *"Telematics = Information + Communication"* technology that has the potential to impact the form and structure of the University beyond anything we can currently imagine. The evolving global information infrastructure has already impacted many facets of our lives. The way we disseminate information, conduct business, manage personal activities, and search for knowledge and information are undergoing profound changes. This technology and its future evolution has the potential of making *telelearning* the new educational paradigm at local (within a given institution) and global (nationwide and worldwide) levels. In the future, universities will advertise and offer courses via the Internet. Students will be able to choose the "best" course in the educational "marketplace" without being limited by spatial (class size limits, geographical proximity to classroom), or temporal (exact time at which the course is offered) constraints. Telelearning will enable the expansion of current course offerings through the addition of material from participating institutions; it will enable the expansion of enrollments. Most importantly, telelearning is the technology that will enable the creation of the Virtual University of the future.

**What is Purdue-On-Line today?** There are many new technical and educational issues related to on-line education that must be addressed. They concern the infrastructure needed to deliver such courses, the on-line courses content development, computer based educational environment, and on-line teaching paradigm. The list of current activities includes:

- *Design and prototype an environment for on-line instruction on stationary and mobile platforms*
- *Research teaching methodologies for on-line instruction*
- *Experiment with a set of traditional courses*
- *Evaluate courseware delivery models/software and on-line courses*
- *Evaluate video servers (hardware/software), videoconferencing, and communication technologies*
- *Assess the overall cost and impact of on-line education*

**Who supports this effort?** The main supporters are: Intel Corporation provides equipment and a student/faculty support of the order of $200, 000 a year for the development of the virtual classroom utilizing mobile and wireless technologies, Purdue University provides a grant of $37,000 a year for supporting the development and maintenance of POL facility and on-line courses, Department of Computer Science provides TA support and faculty teaching credit towards the development of CS on-line courses and classroom equipment, the School of Science has provided support for the virtual classrooms projection systems and application software, AT&T and IBM have provided support for computer and communication equipment.

**What will be Purdue-On-Line tomorrow?** Purdue University needs to create an organization and a physical facility to support activities such as:

- Research on distributed learning
- Training of faculty and students in the technologies needed to create content and deliver it in some on-line form
- Development and management of Internet based courses
- Delivery off-campus and on-campus instruction via the Internet

- Evaluation of internet based courses and educational activities

**Why create Purdue-On-Line?** The Internet has created a new medium for delivering distance education in "asynchronous" and "synchronous" modes in a cost effective way. It is inevitable that Purdue will be forced to develop and deliver Internet based courses in order to compete in the future educational market place. Peer CIC institutions like UIUC, Univ. of Wisconsin and Penn. State Univ. are already deploying courses on the Web. The educational establishment at Purdue must become familiar with this new educational paradigm, the associated technologies needed to sustain it, the organization and cost involved, and the physical infrastructure needed to implement it in a large scale. A recent internal report by the Distance Learning Committee titled "A Consideration of Purdue University's Involvement in Distance Learning" aptly discusses the need for serious effort in this regard [1].

There are many citizens that are both space and time bound that need/want higher education and the Internet is the efficient medium for delivering it. The majority of these citizens are associated with industry. Attracting these kind of students will increase the interactions between University and Industry, thus benefit indirectly the faculty, regular students, and the University as a whole.

**How cost effective is on-line education?** There several studies addressing this issue. It's worth referring to a study with title *"Costs for the development of a virtual university"* by Murray Turroff, http://www.aln.org/alnweb/journal/issue1/turroff.htm. Its importance lies on the fact that it was published 15 years ago and recently was republished to reflect current economic reality. According to this study a) a single classroom building on a physical education campus is estimated to cost $15,000,000 US dollars and b) the non faculty cost required to set up an academic program for 2000 students that is made up of students and faculty scattered around the world is estimated to be $1.8 Million or $900 per student per year. It is assumed that each student has its own computer and pays the internet subscription. This cost is only 10% of the tuition that an out of state Purdue student is paying today.

**What are the non-technical challenges?** We don't see any reasons to delay investing in this new educational paradigm; several other Universities already are doing it. It seems to us that some of the arguments presented against this new form of the University are only justified in terms of a) inertia, b) ignorance, c) technophovia, and the "bricks and mortar" syndrome vs. "silicon and fiber" syndrome; it is easier to get credit for physical artifacts than virtual ones. One has to recognize that education is getting very expensive and that virtual education is better than non education. Whole sale education is provided in most of the freshman courses today and it involves less human interaction than a virtual course of the same level. On-line education can become a significant tool to connect top high school students with Purdue, thus assisting Purdue's outreach efforts.

**Are there historical analogs to telelearning revolution? What was the reaction of the establishment?** We are witnessing the revolution not the evolution of *telematics*. Very soon we will become *symptiotic* with our network computers for home, education, government, health care, and work, just as the industrial revolution was symbiotic with the steam engine and later with electricity and fossil fuel[1]. Paper, *the civilization's first computer*, shows signs of obsoleteness. Techophovia is a natural reaction and defense. Technology was always seen by a society as the "necessary evil" (αναγκαιο κακο according to the Greeks). Let's place ourselves approximatelly 3,500 years ago somewhere in Egypt and follow the conversation between an inventor and a decision maker of the time (quotes from The Judgement of Thamus (Plato's Phaedrus)).

*Thueth (The inventor of writing) declaring his invention to Thamus (the king of great city of Upper Egypt)*

*"Here is an accomplishment, my lord the King, which will improve both the wisdom and memory of the Egyptians. I have discovered a sure receipt of memory and wisdom"*

1. *"Beyond calculation: The Next Fifty Years of Computing"*, P. J. Denning and R. M. Metcalfe, Springer-Verlag, NY, 1997.

To this Thamus replied

*"... Those who acquire it will cease to exercise their memory and become forgetful; they will rely on writing to bring things to their remembrance by external signs instead of by their own internal resources. What you have discover is a receipt for recollection, not for memory. And as for wisdom, your pupils will have the reputation for it without the reality: they will receive a quantity of information without proper instruction, and in consequence be thought very knowledgeable when they are for the most part quite ignorant. And because they are filled with the conceit of wisdom instead of real wisdom they will be a burden to society."*

The arguments against on-line education sound similar to Thamus' reaction. It's our observation that society was unable to stop technology and evolution. Our only alternative is to exploit its positive aspects and constraint its negative aspects through standards and policies.

**What are other challenges to on-line education?** There is a significant difference between publishing the notes/slides of a course on the Web and offering an entire course with pedagogical objectives in some on-line form. For this we need to address seriously some of the following issues:

- Development of pedagogically-sound content for delivery over the Internet
- Incentives for faculty, departments, and schools
- Copyright and ownership issues
- Quality control
- Library support
- Development of new software environments and tools

**What is the initial scope of Purdue-On-Line (POL)?** The technology to aid all Purdue courses with on-line material and conferencing is available today. For the success of on-line education we need to engage ourselves in serious experimentation with courses in which there is minimum teacher-student interaction or high level student maturity and motivation. Our initial activities in on-line education and technology have been restricted to the following objectives:

- Develop, test, and validate a set of high-quality cost-effective Internet based learning services and network technologies to support delivery of on-line courses
- Develop and deliver freshman on-line courses in computer science for engineering and science students; these courses would be open to high school students
- Develop and deliver professional degrees (i.e. Software Engineering, Computational Finance, and Veterinary Medicine)
- Develop and deliver technology oriented courses (i.e. Web, Window Systems, and Software Suites)
- Purdue University becomes not only the provider but leader in distributed education

**Guide to the reader.** This report describes primarily a) the design of the Purdue-On-Line facility and on-line course CS158a for teaching computer programming concepts and C/Java languages and b) the infrastructure available for the implementation of POL and delivery of CS158a. The first section defines distributed learning, compares it with the conventional TV/Video based distance learning paradigm, and assess its potential and impact. In the second section we present the functional specifications of the Purdue-On-Line (POL) facility designed to deliver and manage any course through the Intranet or Internet networking platform. The third section states the problem with the current paradigm of teaching freshman computer science courses and lists the design objectives of the new CS158a course. The distributed learning framework utilized in CS158a course is discussed in section 4. We describe the content of the CS158a and its delivery modes in section 5. Our proposal for an on-line MS professional degree in *Software Engineering* are presented in Section 6. We review the available tools for implementing POL in Section 7 and present our current choices of tools for supporting asynchronous delivery of virtual courses in Section 8. The experimental course material and presentations of CS158a can be found in the following POL Web site URL: *http://pol.cs.purdue.edu/*.

## 2.0 Distributed Learning Paradigm

We begin by briefly sketching what **distributed learning** means, in particular how it differs from the traditional notion of distance education which uses communications to extend the reach of the lecturer. The principal characteristic of any form of distance learning is that the student does not have to be present in a classroom in order to participate in the instruction. Broadly defined, **distance learning** is any approach to education delivery that replaces the same-time, same-place face-to-face environment of a traditional classroom. **Distributed learning** is a type of distance learning that we define as technology-enabled, team-learning focused education, facilitated by a content expert, and delivered anytime and anywhere.

The current practice of distance education is exemplified by the following familiar examples:

- Mind Extension University in the US, a venture by Jones InterCable in partnership with the University of Colorado at Fort Collins. This involves videotaped or live lectures being shown on some local cable channels. Questions are asked only by those physically attending the lecture at the Fort Collins campus, or by those who gather in designated remote sites with a phone link to the instructor.
- Many Universities offer courses remotely via satellite, with videos of the lecture available for the students who miss the lecture or want to see it again. Questions could be asked by calling the instructor via an 800 number, during the lecture. At the ITESM Institute in Monterrey, Mexico, the large number of students and the poor quality/availability of telephone lines have caused them to follow an email-based approach for handling the questions: email questions are screened and interpreted by assistants to the lecturing professor, and they either answer the questions themselves (on-line or off-line) or, based on their judgement, they relay the question to the lecturer (if, for example, the question is judged to be of interest to the whole class).

The traditional approach, as exemplified above, inherits unaltered the notion and structure of a class from the classroom in a building scenario. Its only major advance is to remove the barrier of distance and the limitations on the size of the target audience. In other words, the physical presence of the student in a particular room is no longer required. On most other pedagogical issues that face classroom instruction, it offers nothing new. The proposed approach, as will become clear in the following pages, differs radically from the above TV-based traditional ones. Let us point out some of the more significant differences:

- The *interactive multimedia* nature of the approach: The student controls, with some point-and-click device (e.g. mouse), the flow of the lecture. Contrast this with the traditional approaches where all the students take the class at a predetermined time (sometimes in a predetermined room that has the needed satellite reception facilities) and see the same lecture on the TV screen.
- The *self-paced* nature of the approach: Slow learners use their control over the flow of a lesson to make sure they have a slow pace, request many examples, etc. *Mutatis Mutandis*, the faster learners are not penalized either. Contrast this with how today's lectures are targeted to the average student, penalizing the slow learners (who are lost) as well as the fast learners (who are bored).
- The *adaptive* nature of the approach. The software can include some simple AI (Artificial Intelligence) mechanisms for learning about the level of the student. For example, a student repeatedly fumbling the mathematical portions of exercises could be given a choice, by the software, to undergo an on-the-spot remedial coverage of the problem topics. Contrast this with the current situation, where we either loose such students or are forced to inflict a review on all of the class.
- The potential for *automating* the testing process for some types of courses (and having the exams done "on demand", whenever the student feels she/he is ready). Not only is this more convenient to the students but it also frees up the

instructor for more productive endeavors than repetitive grading. Such a scenario helps people who know the material, but lack what are commonly described as exam taking skills.

- The potential for offering/testing knowledge in basic units with a *finer granularity* than the traditional one-semester course. This has the potential of increasing the "continuing education" type of enrollment, since an employed engineer who needs X, Y and Z can focus on just these topics instead of having to take a large course that includes these topics.

On the other hand, there are difficulties peculiar to our approach:

- The problem of *charging* for electronic access. This is the issue of how to avoid, e.g., a student sharing his access rights with non-students and costing large amounts of uncollected tuition. This problem is not as acute in the current situation, in which it is easy for the instructor to notice the physical presence, in his very popular lecture, of a large number of people not registered for the course. (In an encouraging development in that area, Folio Inc. has recently announced a method of using cryptographic protocols for solving the special case of copyrighted newsprint.)
- The *development and maintenance cost* of the educational software and courseware, which far exceeds those of a traditional course (cf. the previous comment about recording many versions of a lecturer's coverage of a topic X).

## 3.0 On-Line Freshman Education

The current freshman education of our students is primarily based on *wholesale lecturing* than *individual tutoring.* This teaching paradigm puts the burden of learning on students only and is unsuitable for teaching science and engineering. As a result many well motivated students get frustrated, discouraged, and leave these schools or get graduated with an incomplete education. True teaching and learning is much more than information and its transmission. We agree with the opinion that education is based on *mentoring*, *internationalization*, *identification*, *role modeling*, *guidance*, *socialization*, *interaction*, and *group activity.* We realize that the cost of delivering personalized education is very high in the current education environment. However, the utilization of telematics (i.e. computer based information and communication) technologies in the classroom can increase individual tutoring and student/instructor interaction and communication without significant additional resources. Moreover, the potential to deliver these courses in a distance mode and the expected additional revenues can off-set the infrastructure cost required. We strongly believe that the ability of delivering high quality customized and individual education in a cost-effective way will influence the prosperity of Purdue University in the upcoming competition from Cyber-U's and the already started transformation of private educational institutions!

We are currently designing and delivering a *computer programming course* (CS158a) for engineering and SoS students. The associated material under development is multimodal and customizable for the individual student. We are developing and testing a learning paradigm and environment associated with this course that i) puts the responsibility of student performance to the instructors, ii) improve student performance, iii) decreases the time to learn by at least 30%, iv) makes the course material, produced in consultation with the best instructors in given subject area, available in multimedia form on CD-ROM and Web "anytime" and "everywhere", and iv) delivers the course in direct, studio, telepresence, and distance-learning mode.

## 4.0 On-line MS. Degree In Software Engineering

A group of computer science faculty in collaboration with the industrial affiliates of Software Engineering Center (SERC) at Purdue are designing a new master's program in software engineering to serve Purdue students and outreach constituents who are time and space bound. For this, the model of synchronous distributed learning is considered and researched.

The MSE program is targeted to be offered starting in the fall of 1997. The program will use the Internet and POL facility including the advanced two-way audio-video conferencing technologies proposed to deliver educational material to on-and off-campus students. Off-campus students are expected to be sponsored by companies interested in furthering the education of their employees in advanced Software Engineering.

The infrastructure support for the MSE degree will consist of hardware and software in support of the MSE program. The hardware will consist of (i) equipment for audio-video conferencing (AVC) and (ii) multimedia PC's and workstations for use by students and instructors of the MSE program. The software will consist of (i) systems to support the delivery of educational material, (iii) software engineering tools necessary for use in the laboratory component of the MSE program. The AVC equipment will be used to deliver the MSE courses and support the interaction between instructor and students during the classroom and office hours. Multimedia PC's and workstations will be used as servers for the educational material on the Web, for development of software, and for laboratory experiments by the students.

Two PC's will be text, audio, and video servers for the educational material placed for access via the Internet by the students. Four PC's will be used by graduate and undergraduate students for software development. Sixteen PC's will comprise the laboratory associated with the MSE program. In addition we plan to acquire software engineering tools for use in the laboratory. The computer sciences laboratory 111 will be used to deliver the MSE and house the requested infrastructure. The facilities in CS111 and CS175 laboratories will be used to carry out this project. Some of the equipment in these two laboratories have been donated by Intel Corporation.

**Status of the MSE program.** A proposal for the MSE program is currently under preparation. Industrial affiliates of the Software Engineering Research Center (SERC) have been given a presentation based on a preliminary proposal. The feedback obtained from them will be incorporated in the design of the curriculum. Companies other than SERC affiliates (Motorola and Tellabs) have also been contacted to explore the possibility of their sponsoring candidates for the program. Tellabs has given positive indications that they will sponsor candidates starting in Spring 98 to attend the graduate course in Software Engineering. This course will be a part of the MSE program. The Spring 97 offering will serve to test the offering of SE courses in the distance education format.

We are also exploring the possibility of jointly offering one or more courses in the MSE program to students of both Purdue and the University of Oregon at Eugene. Such a joint offering, coupled with offering to employees of software companies, is likely to increase in enrollments at Purdue in critical areas and provide excellent opportunity for serving the needs of the US industry in education in SE.

**Impact of the proposed work.** We foresee the proposed work impacting two activities at Purdue. First, the infrastructure will be of direct benefit to students who enroll in the MSE program. Second, the software developed for the delivery of educational material will be usable by other educational program at Purdue, especially the ones that want to expand using the distributed education format. In addition to the above, the infrastructure will allow efficient operation of the MSE program which in turn will serve the Purdue well amongst companies who sponsor employees to the MSE program.

## 5.0 Purdue-On-Line Project

In this project we seek to create and maintain a facility for developing, implementing, and delivering Intranet and Internet based virtual courses. We are currently researching and experimenting with Internet based telelearning educational paradigm by offering a "virtual" course in "computer programming" to a limited number of students. It's worth noticing that the characteristics of this new educational paradigm make it different from existing video based learning paradigms. Internet based telelearning supports interactive, multimedia, self-paced speed, exam-on-demand, programmed educational modules covering different aspects of the same topic at varying levels of difficulty, adaptivity, and usefulness for learning disabled student.

The design of this experimental program satisfies the following criterion: a) maintaining the same quality as traditional classroom based courses, b) existence of a significant student population which will be interested in the telecourses (both credit and non credit), c) strong support and commitment from the academic units and deans, and a desire to see this effort continue long term, d) reuse of existing resources, research and faculty expertise, and e) produced material made available in multiple formats suitable for both real time and asynchronous delivery.

There are three distinct aspects to this project: technological, educational and organizational.

**Technological Tasks.** The goal of the technological activities is to develop (purchase and/or engineer) the infrastructure needed to develop and operate the Purdue-On-Line facility both at the individual virtual class level and also at the virtual university level. There are already several commercial software packages that are available for similar activities and one of our tasks will be to review and evaluate the viability of licensing such software instead of developing it. The specific goals for this task are:

- Adapt and advance technology to support a telelearning framework based on Internet infrastructure
- Design, implement, and evaluate a prototype facility for providing on-line virtual courses and a software environment for "virtual courses and classrooms"
- Design and implement an on-line server for delivering virtual course
- Design and implement an environment for the virtual university

The initial architecture of the Purdue-On-Line facility is concentrated on the development and delivery of virtual courses primarily, rather than the realization of the virtual university. The next section discusses the design and architecture of the virtual course environment.

**Educational Tasks.** The educational goals of POL are to study the pedagogical aspects of teaching and learning in the POL environment. We expect to interact with faculty from the school of education for these tasks. As prototypes, we will develop several virtual courses that will be delivered via POL. The specific goals for this task include:

- Develop and implement the new education paradigms of *learning anywhere* and *learning on-demand*
- Develop, implement, and evaluate "virtual multimedia courses" in several scientific, medical, agricultural and engineering areas

**Organizational Tasks.** An important task of POL is to develop the concept of a *virtual university*. There are several other efforts already in this regard and we expect to leverage from their work. The specific goals for this task include:

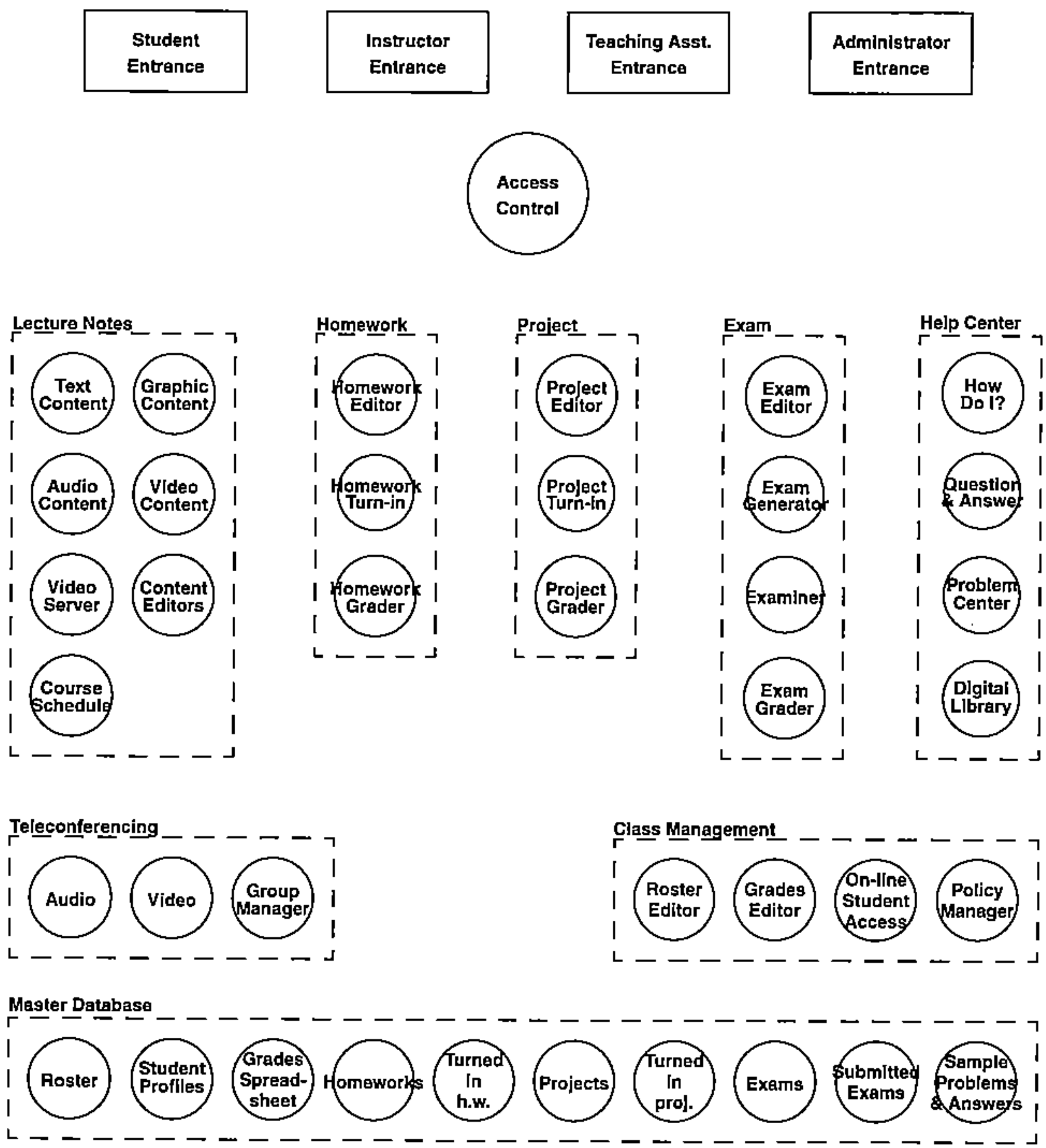
- Develop the institutional infrastructure to admit and administer "virtual" students
- Study issues of accounting and security

## 6.0 Architecture of the POL Course Development and Delivery Environment

The design of the course development and delivery (including administration) environment follows the design and structure of the traditional classroom in that it provides all of the facilities of the traditional classroom (and more). The architecture in terms of the main subsystems and their components is illustrated in Figure 1 on page 9. In the rest of this section we describe each of the subsystem. The next section discusses the implementation of this architecture using several servers and other components.

**System Access.** Access to all parts of the course, except for the first page ("homepage") is access controlled. Access is allowed at several access levels: student, teaching assistant, instructor or administrator. Access is managed using a personal access code (PAC) scheme using the class rosters and other information by the department / school / university administration. The access control subsystem represents the input interaction between the university and a class.

**FIGURE 1.** Architecture of the POL Virtual Classroom Environment: Component Subsystems View



**Lecture Notes.** This subsystem is the main activity area for a classroom. Content may be provided in any media, including text, graphic, audio and video. We expect to organize content in a hypertext style around a course schedule which allows the student to easily navigate the course lectures. Content development editors are used to develop content. Content must be designed to support self-paced, adaptive learning. We consider the technical facilities for developing and delivering video content separately as that requires special hardware / software.

**Homeworks, Projects and Other "Off-Line" Assignments.** These types of assignments are considered *off-line assignments*; i.e., the instructor *hands out* these assignments and they are done in the students' own time/space and *submitted* to the instructor at a later time. The functionality of these components include an editor for creating the assignments and uploading them to the class system, a *turnin* facility for students to upload their responses to the assignment and a grading environment to support grading of the assignments.

**Quizzes and Exams.** Quizzes and exams are treated in the same way (at the architecture level). These may be taken in a pseudo off-line mode (which corresponds to the traditional exam format: the student receives the entire exam at once) or in an on-line mode, where the examiner dynamically selects the next question based on the students responses so far. The latter is similar to the approach used in computerized GRE examinations, for example, currently. This subsystem consists of the exam editor for the instructor, the exam generator to generate the exam for off-line or on-line operation, the examiner to administer the exam to the student and the exam grader.

**Help Center.** The help center is an essential component of the classroom. This consists of a reference desk containing various useful information (including "How do I..." type information), a question and answer bulletin board type environment to allow students to ask questions from one another and the instructor (as well as to review previously asked questions and answers), a problem center to provide a repository of sample problems and solutions for the students to learn from and (access to) a digital library.

**Teleconferencing.** This facility enables both student-instructor and student-student interaction. In addition to standard audio/video/text/graphic teleconferencing facilities, a major component is a virtual group manager which supports creating communication groups to allow students to work in group projects. For basic telecommunications, we intend to use existing commercial off-the-shelf facilities such as Netscape CoolTalk or Microsoft NetMeeting.

**Class Management.** The class management subsystem supports all administration aspects of the class. Depending on the access level of the user, the level of functionality is varied. The overall facilities include a roster manager to administer the class roster, a grades manager to administer the class grade book, a policy manager to administer class policies (including grading policies) and an on-line student access system to allow students to browse their own records.

**Master Database.** The master database is really a collection of databases that contain all records for the class. These records include the class roster, the class grades, homework, project and other handouts, exams, sample problems and answers, turned in assignments and submitted exams.

## 7.0 Implementation of the POL Course Development and Delivery Environment

One of the first decisions that need to be made for implementation is whether to buy a fully-functional commercial system, to acquire and adapt/modify a commercial/university system or to develop a system on our own. We have done a preliminary search of available software and have concluded that there is no available system that meets all of our requirements. Hence, at least for the current prototype stage of POL, we have decided to design and build a course development and delivery environment ourselves.

The architecture described above is being implemented using four components: a client for user access, a Web browser, a Web server and a management server. Each of these components is briefly described below and their inter-relationships are shown in Figure 2 on page 11.

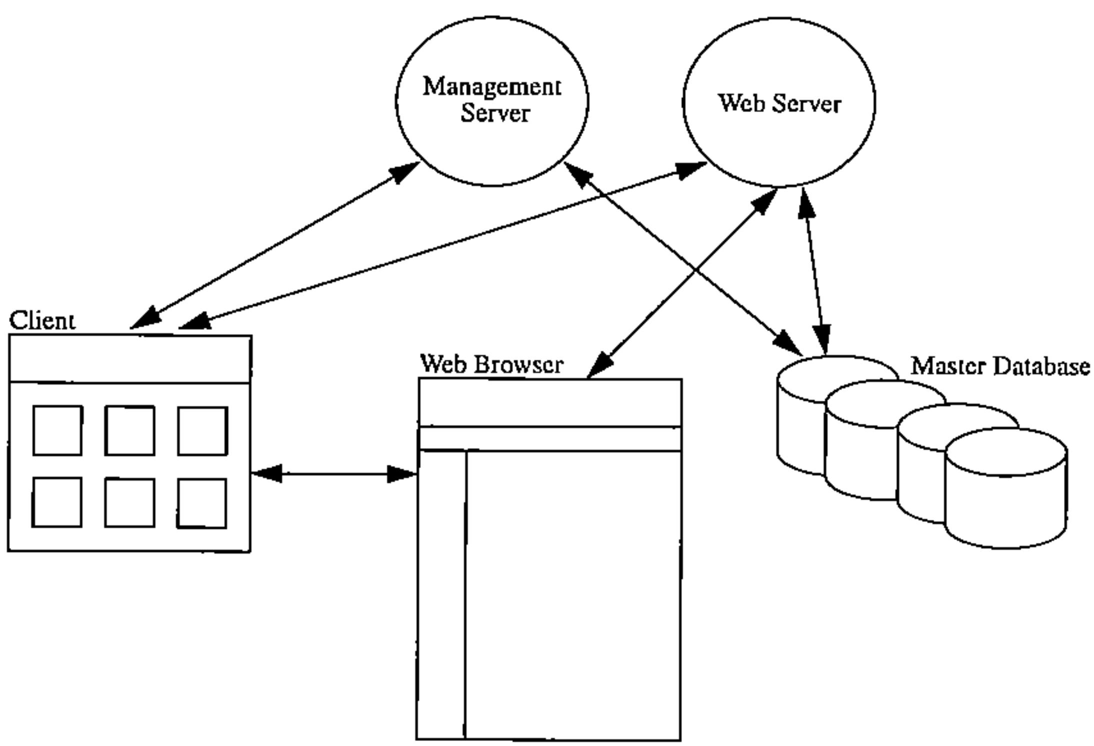
**Client.** The client environment is the access tool for all users of the course development and delivery environment. Depending on the type of user currently logged in, the capabilities of the client will differ. There are several choices for the architecture of this client: as an applet, as a traditional application or as a Castanet channel [3].

**Web Browser.** A standard Web browser is used to access and navigate "normal" Web content (HTML and other documents, course schedules, help center, etc.). The browser will be initially controlled by the client and then by the user.

**Management Server.** This server performs several important POL tasks such as access control, on-line records access, exam generation and administration and overall database management. The client uses this server as its secure counterpart and also to authenticate new users into the system.

**Web Server.** A standard Web server (with optimized support for accessing external code) is used to deliver "normal" Web content to the client and to the Web browser. All content will be access controlled using a fully secure mechanism (based on personal access codes and single-session keys).

**FIGURE 2.** Architecture of the POL Virtual Classroom Environment: Functional View



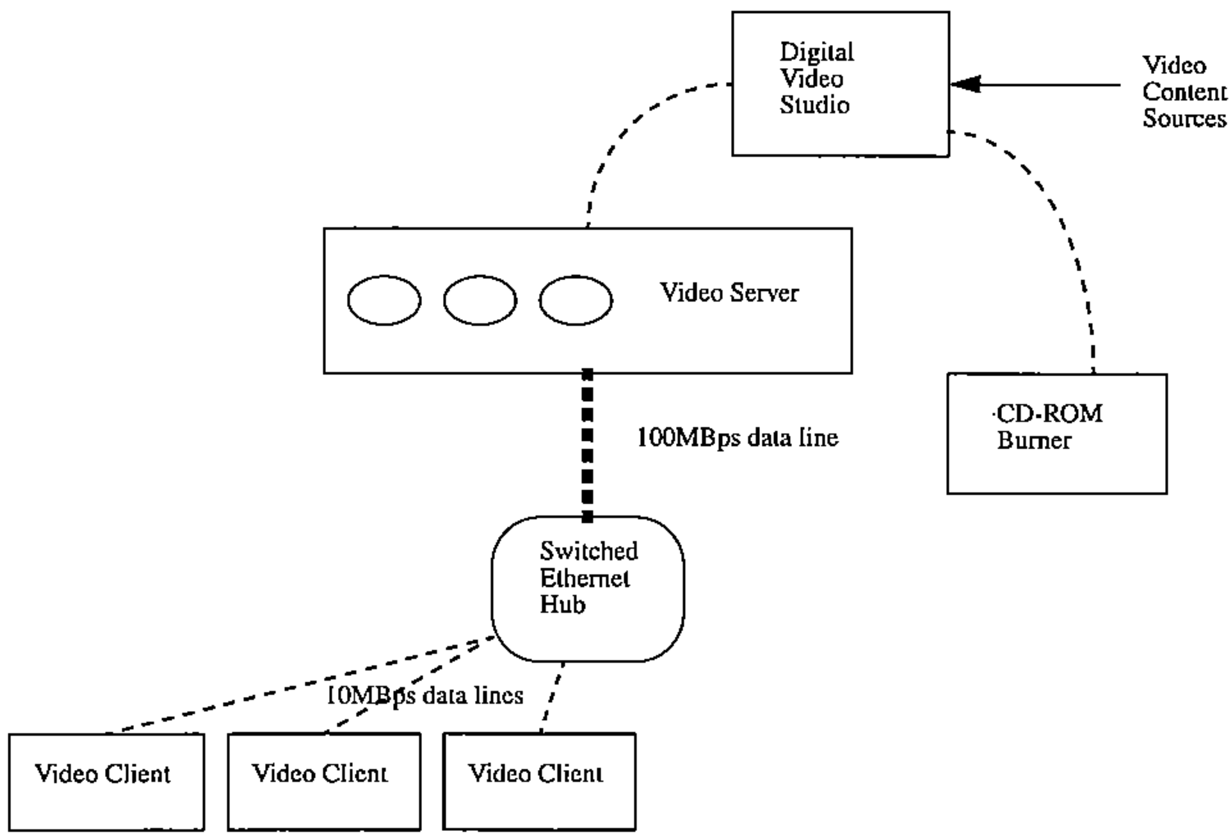
## 7.1 Video Content Development and Delivery

The development of video content must be done by the individual instructors. POL will have a digital video editing facility to convert VHS and SVHS format video content to digital MPEG-1 format. The resulting files will then be transferred to the POL video server for delivery.

While each course server will keep track of the video contents of each class, the video itself will be delivered by one or more video servers. We consider video needs for both intranet and internet use. Video on the current public Internet is not realistic at this point due to the high rate of congestion on the Internet. However, several key technologies are emerging rapidly currently (based on RTP (Real Time Protocol)) and we expect to adopt these at the earliest possible time. In the mean time, an alternative is discussed in the next section.

For intranet video, i.e., for virtual courses offered within the Purdue Data Network, we are setting up an Oracle Video Server on the machine pol.cs.purdue.edu. Even within the current intranet, video delivered across multiple networks is unusably slow and/or choppy. Hence, for initial prototying, we are setting up a special laboratory with custom switched ethernet networking to support the delivery of video content from a video server. Figure 3 on page 12 illustrates the architecture of the POL video environment.

**FIGURE 3.** Architecture of the POL Video Environment



### 7.2 Virtual Course Content on CD-ROM Media

As mentioned above, video content delivery via the Internet is not yet feasible. An alternative is to burn CD-ROMs with the video content and deliver that via regular mail to course participants and have Web-based content refer to the local CD-ROM for video material. We are purchasing a CD-ROM burner to support this activity.

## 8.0 CS158a: A new Paradigm for Teaching Computer Programming

Computer technology has already become an integral part of several aspects of life. It supports the management of our personal and business activities, and can be found in almost every human artifact. It is used as a learning aid and enabling technology in every social, scientific, and engineering discipline. Taking advantage of the opportunities and potential that this technology offers, either as users or as developers, requires some basic understanding of the underlying "computer science". This is regardless of the field of intellectual or professional endeavor of the user. Unfortunately, there is a big gap between current availability of computer technology and computer science education. One can argue convincingly that computer science courses in K-12 are considered as secondary intellectual material, something that "nerdy" students like. Even at the university level, we continue to teach students programming-in-the small in some one-to-many (usually more than 300 students) setting, using primarily text and plastic foils without taking advantages of our own technologies. This is inspite of the promising "ease-of-use" and "plug-and-play" technologies, the plethora of available applications and the rich, high-level functionality and concepts supported by application programs. The effective use of these technologies requires a new form of programming education that can be described as "programming-in-the-large." This involves teaching students the art of problem solving using high level computational tools, besides just teaching them details of some imperative language. The rapid exponential changes in computer technology demands continuing education even for reasonably knowledgeable professionals, and underscores the need for effective software tools and laboratories dedicated to such education.

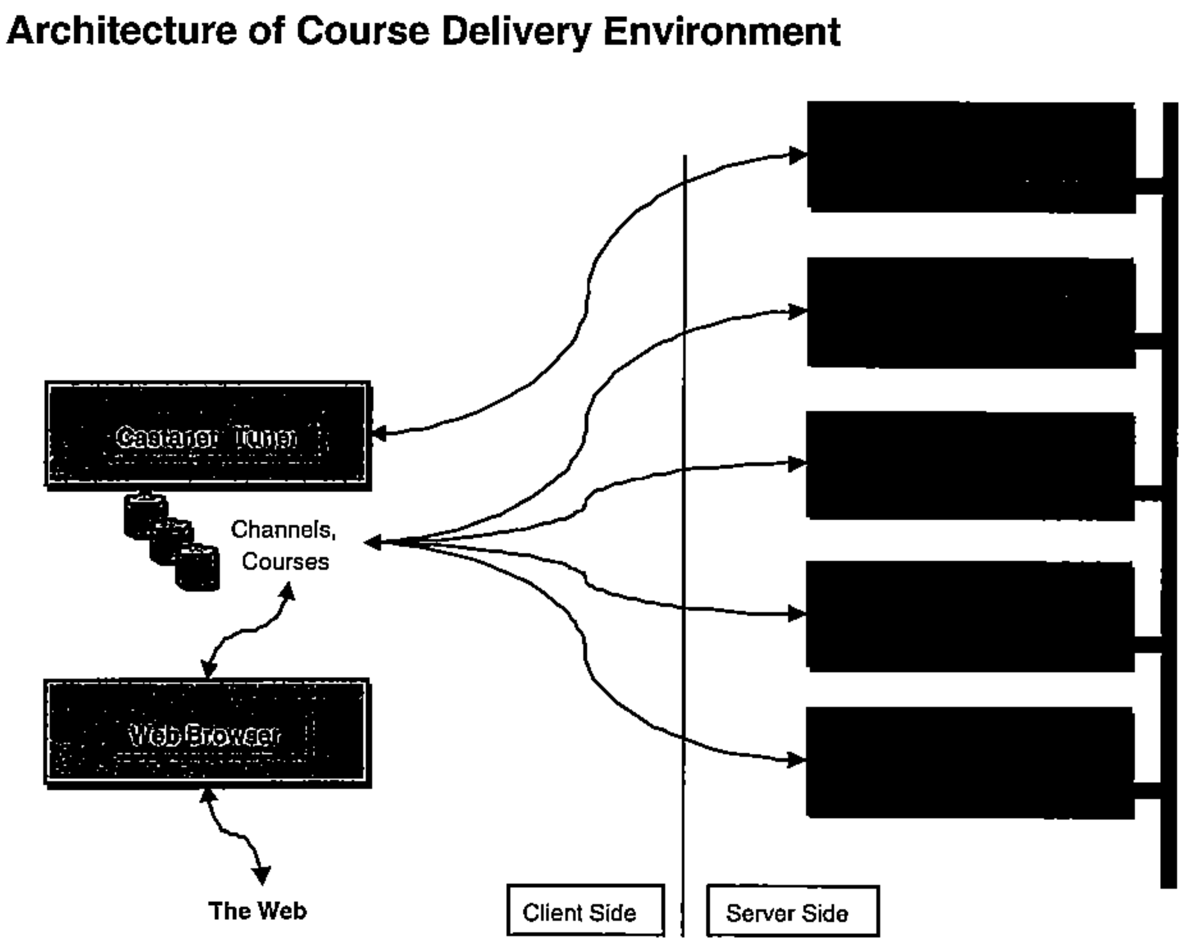
In the CS158a project we attempt to address the following research issues: a) **develop new paradigms for teaching computer programming and computer science courses in general using information technology, b) redesign the classroom & laboratory and make it available in some virtual form, c) develop software environments for delivering courses "anytime" and "everywhere" using such facilities, and, d) develop and evaluate an introductory computer science programming course material suitable for telelearning using this labware.**

## 9.0 CS158a: A virtual course in "Programming in C and Java"

The course objectives are to train and educate students in the following subject areas and associated technologies:

- PC Window environment, file system, Word processing and tools.
- Introduction to Internet, Web environment, and Web tools.
- Electronic communication: E-mail and electronic forums.
- *Mathematica* Programming Simulator.
- Study of Computer Techniques and Problem-Solving Methods for Applications in Engineering and the Physical Sciences.
- Unix fundamentals and Programming in C and Java (This activity is supported by a special tutor implemented in Java and runs on multiplatforms. The tutor allows users to rlogin to Unix servers).

**FIGURE 4.** Architecture of Course Delivery Environment




## 9.1 The PC computer and communication environment

- Basic familiarity with windows and system tools (file system, printing etc.).
- Internet, email, news as information gathering and sharing tools.
- Web related material, use of a Web browser (e.g. Netscape) as an integrated environment to access HTTP, Gopher, Mail, News, Wais protocol based material.
- Basic familiarity with tools for word processing and presentation.

## 9.2 The *Mathematica Symbolic and Numeric Simulator*

It includes the training of operating this powerful problem-solving environment (PSE) and computer science concepts and methods such as

- Computer Systems
- Basic Problem-Solving Techniques (Algorithm Design, Programming Constructs)
- Non-Numerical Algorithms and Data Structures (List Structures, Sorting, Searching, etc.)
- Computer Graphics (Graphs, Charts, CAD Methods, etc.)
- Numerical techniques (Solving Systems of Linear Equations, Solving Nonlinear Equations, Data-Fitting Methods, Numerical Integration, Other Numerical Applications)
- Statistical techniques
- Problem-Solving Methods using modular programming

In addition the students have access to a tutoring system for Mathematica.

## 9.3 Mathematica To C Intepreter

External intepreter for use with Mathematica clients to convert mathematica code to 'C' based code. Useful for teaching students with knowledge on Mathematica code to program in 'C'.

## 9.4 Programming in C and Java

The programming concepts and techniques demonstrated using *Mathematica* are revisited in C&C++ and Java. The students use the CD-ROM materials by Deitel & Deitel, Prentice Hall and a question and answer sessions corresponding to lectures.

## 9.5 Course Implementation And Delivery

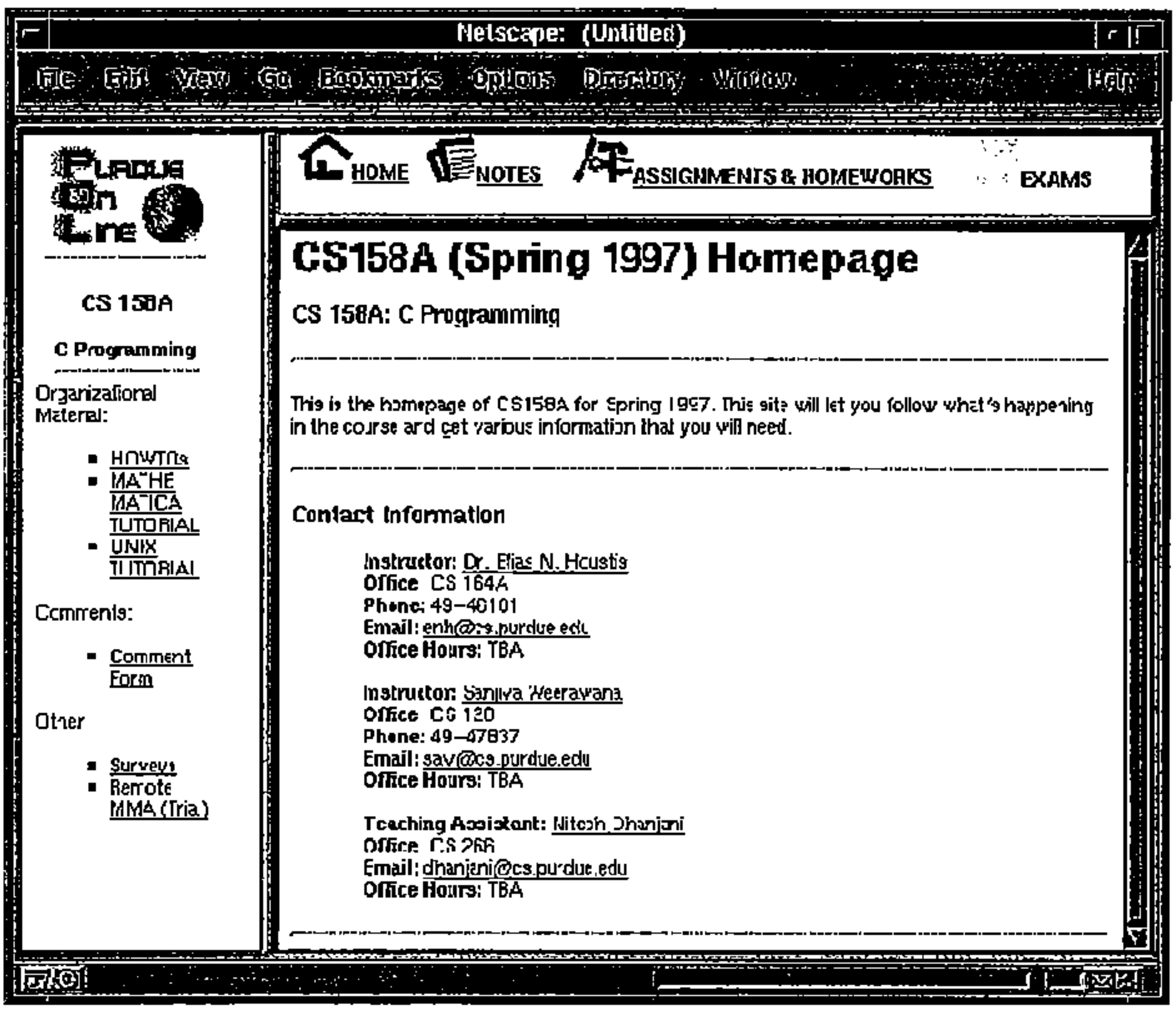
The course material (live lectures, video lectures, slides, assignments, and tests) will be available through some form of videoconferencing, CD-ROM, Web server, and Video server. For the delivery of the course we assume that the students has access to a workstation with CD-ROM drive, Internet connection, videoconferencing support.

**Direct laboratory Delivery Model.** We are currently experimenting the development of this course on a learning environment consisting of two laboratories of multimedia Pendium based PCs, connected to the PUCC network all running Window NT system, Mathematica, Netscape 3.0, Microsoft Office, Visual C++ and Java. The classrooms are equipped with projection systems connected to the instructor's PC. In addition these students have been provided for the duration of the course with a ThinkPad notebook equipped with wireless technology which he/she can take home and still be connected with the cyber classroom.

**Asynchronous Delivery Model.**

**Synchronous Delivery Model.** The synchronous on-line model will be supported by two-way video utilizing Intel ProShare videoconferencing technology, LearnLinc and Purdue-On-Line software, and Internet/Intranet/ISDN communication technologies. Figure 1 displays the architecture of this synchronous learning model using ProShare. In addition, the Purdue-On-Line (POL) group is exploring collaboration with Hughes Corporation to use satellite broadcasting and DirecPC technologies to deliver on-line courses. Figure 2 depicts the architecture of the satellite based synchronous learning model.

**FIGURE 5.** Web page of CS158a on-line course.



## 10.0 Available Tools for Implementing POL

There are many tools available for realizing (part of) POL. In this section we briefly summarize important tools available under the categories of conferencing software (for multimedia conferencing), multimedia delivery software, synchronous course management systems, asynchronous course management systems and virtual university systems.

**FIGURE 6.** Current hardware supporting POL facility

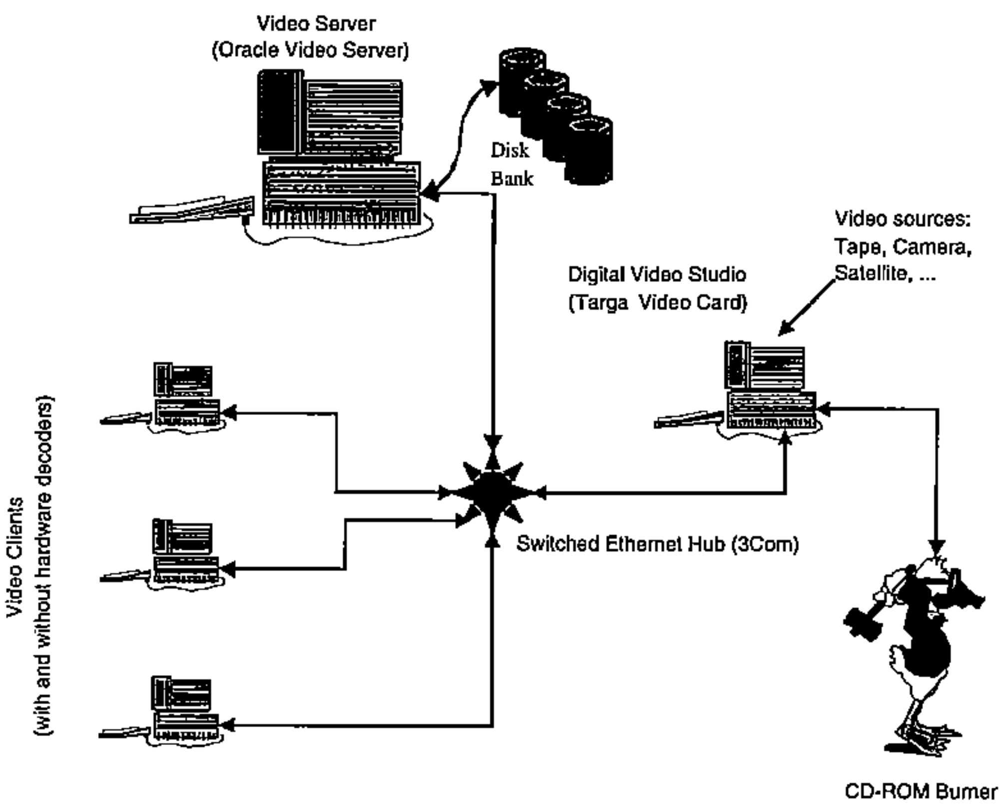
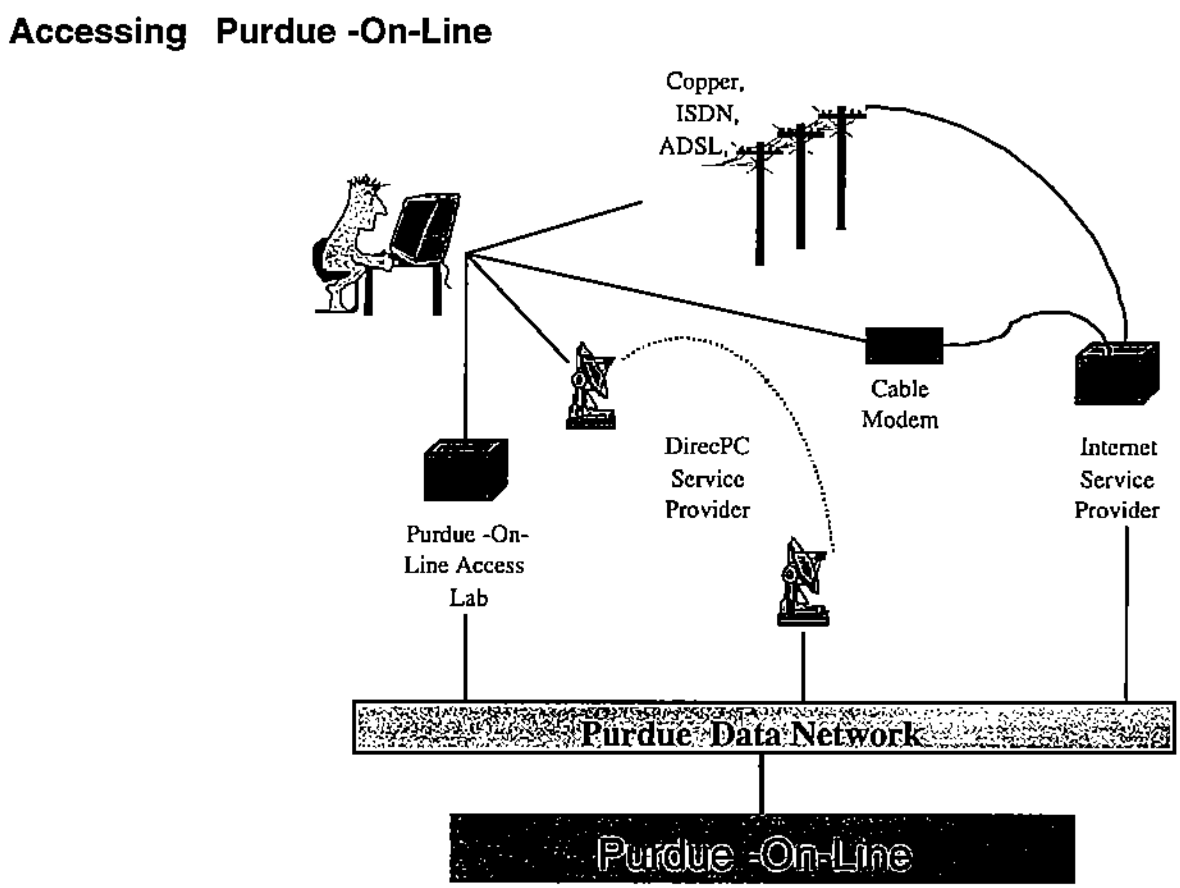


FIGURE 7. Hardware facilities foraccessing Purdue-On-Line server and courses.



## 10.1 Conferencing Software

The table below summarizes available conferencing systems. Key for "Type": Audio, Video,Text, Whiteboard, Messaging (e-mail), Bulletin Board.

TABLE 1. List of available conferencing systems.

| Product | Type | Platforms | Cost | Comments |
|---|---|---|---|---|
| Netscape Cooltalk | A, T, W | Most | 0 for academic | Audio communication tool, embedded in Navigator releases.<br>http://www.netscape.com |
| Netscape Communicator | A, T, W, M, B | Most | 0 for academic | Latest web browser by Netscape.<br>http://www.netscape.com<br>More security features added in its Java Virtual Machine implementation. |
| Netscape Gold 3.01 | A, T, W, M, B | Most | 0 for academic | Popular web browser by Netscape.<br>Can run Vxtreme client |
| Microsoft Netmeeting | A, T, W | WinNT,<br>Win95 | 0 | http://www.microsoft.com/netmeeting<br>Audio communication tool with the ability to share applications. |
| H.320 products | A, V | Most | Unknown | New standard for teleconferencing which is being adopted by various proprietary vendors.<br>http://www.aeta.com/html/interview.html |
| FirstClass | T, M, B | Win95, WinNT, MacOS | 0 | http://www.softarc.com/FC/FC.HTM<br>FirstClass is a high performance e-mail collaboration system that's easier and more fun to use than traditional groupware or intranet software. |
| POP-based mail | M | Most | 0 | |
| Usenet | B | Most | 0 | |
| Proshare | A, V, T, W | Windows 3.x,<br>WinNT,<br>Win95 | $1200 | Video Conferencing tool with application sharing capability.<br>http://www.intel.com/proshare/videophone. |
| CuSeeMe | A, V, T, W | Most | $69 for client.<br>$1298 for server. | http://www.cuseeme.com<br>Popular video conferencing tool. Applicable for modem use also. |

## 10.2 Media Delivery

The table below summarizes available media delivery systems. Key for "Type": Streaming Video (includes audio), Streaming Audio, Video File Format.

TABLE 2.

| Product | Type | Platforms | Cost | Comments |
|---|---|---|---|---|
| Oracle Video Client/ Server | SV | Win3.11, WinNT, Win95, Solaris | low for academic, high for others | Provides full-screen MPEG-1/2 quality video. Useful for intranet. http://www.oracle.com/products/oracle7/oracle7.3/html/video_opt.html |
| VXtreme | SV | Most | $50 per stream | Video streaming with synchronous html flipping. Need Java enabled browser. http://www.vxtreme.com |
| RealPlayer / RealVideo | SV | Most | $29.99 for client. $995 for server supporting 60 streams | Live and archived streaming of audio and video. http://www.realaudio.com |

## 10.3 Collaborating Software

The table below summarizes available application sharing and desktop mirroring tools. Key for "Type": Application Sharing, Desktop Mirroring

TABLE 3. List of available application sharing and desktop mirroring tools

| Product | Type | Platforms | Cost | Comments |
|---|---|---|---|---|
| ProShare | AS | Windows 3.x, WinNT, Win95 | $1200 | Video Conferencing tool which has the capability of sharing applications. http://www.microsoft.com/netmeeting |

TABLE 3. List of available application sharing and desktop mirroring tools

| Product | Type | Platforms | Cost | Comments |
|---|---|---|---|---|
| Microsoft Netmeeting | AS | WinNT, Win95 | 0 | Audio Conferencing tool which has the capability of sharing applications. http://www.microsoft.com/netmeeting |
| PC Anywhere | DM | WinNT, Win95 | $149.95 | Mirrors Desktop of remote machine, useful tool for debugging. http://www.symantec.com/pcanywhere/index_product.html |

## 10.4 Content Delivery Sources

The list of existing organizations supporting some form of on-line education cab be found in

TABLE 4. Organizations involved in some form of on-line education.

| Organization | Description |
|---|---|
| RealEducation | Builder and manager of complete on-line campuses and continuing education centers while using various available tools. http://www.realeducation.com |
| Asymetrix | Consultant on howto efficiently author, deploy, and manage learning applications via the internet and the intranet using various multimedia applications. http://www.asymetrix.com |
| IBM Global Campus | An education and business framework that helps colleges and universities use computer networks to redesign learning, teaching and administration. http://ike.engr.washington.edu/igc |
| NovaNET | An on-line computer based education and communications network with instructional material in more than 150 subject areas. NovaNET currently delivers more than 2.5 million hours of instruction each year to adult and young adult students throughout the United States. http://www.novanet.com |
| Centra | A comprehensive resource center with links to various distant learning education sites and a collection of its own material. http://www.centra.com/DISTANCE/INDEX.HTML |

TABLE 4. Organizations involved in some form of on-line education.

| Organization | Description |
|---|---|
| ILINC | ILINC(Interactive Learning International Corporation) develops distance learning software that increases learning quality through a combination of instructor led and self-paced , interactive, multimedia learning tools.<br>http://www.ilinc.com |
| IRI at Old Dominion University | IRI(Interactive Remote Instruction) melds high speed networking, television, and computer technologies to allow for distance learning over the internet.<br>http://www.cs.odu.edu/~tele/ini |

## 10.5 Asynchronous Content Delivery

The table below summarizes available course content managers .Key for "Type": Grading Facility, Misc. Content Delivery

TABLE 5. List of available course content managers.

| Product | Type | Platforms | Cost | Comments |
|---|---|---|---|---|
| Lotus Learningspace | GF, MCD | Most | $23 for one client.<br>$580 for Domino Server | Lotus Notes and Domino integrated Asynchronous distance learning tool<br>Web-based and Lotus Notes client based.<br>http://198.114.68.60 |
| Mallard | GF, MCD | Unix | 0 for academic | Interactive Web-based educational software system developed at the University of Illinois.<br>http://www.cen.uiuc.edu/Mallard/Mallard_nest.html |
| Cyberprof | GF, MCD | Unix | 0 for academic | Interactive Web-based educational software system developed at the University of Illinois.<br>http://www.cyber.ccsr.uiuc.edu/cyberprof/general/homepage/Newpage/toplevel/welcome.html |

### 10.6 Selected Tools for Implementing POL

Based on our evaluation of the various tools we have selected to base the implementation of the POL on the tools listed in the Table 6 on page 23.

TABLE 6. The tools selected to implement the first version of POL

| Functionality | Product |
|---|---|
| Browsing, E-mail, and audioconferencing | Netscape Gold 3.01 |
| Videoconferencing | ProShare and CuSeeMe |
| Asynchronous content delivery | Lotus Learning Space |
| Synchronous content delivery | LearnLinc |
| Video on demand | Vxtreme, Oracle Video Server/Client |

### 10.7 Selected Tools for Implementing CS158a

The on-line environment for delivering CS158a consisits of the tools listed in Table 7 on page 23.

TABLE 7. The asynchronous distributed learning environment for CS158a will be supported by the listed tools.

| Functionality | Product |
|---|---|
| Browsing, E-mail, and audioconferencing | Netscape Gold 3.01 |
| Videoconferencing | CuSeeMe |
| Asynchronous content delivery | Lotus Learning Space |
| Video on demand | Vxtreme, Oracle Video Server/Client |
| Compilers | Microsoft Visual C/C++ and Java++ |
| Mathematica to C interpreter | Purdue's MtoC tool |
| Multimedia Material in C/C++ and Java | CD-ROM materials by Deitel & Deitel, Prentice Hall |
| Talking head lectures with slides | Vxtreme |
| Test on demand | Purdue's tool |
| Unix environment | Java based Unix environment |
| Tutorials | Web tutorial's on tools |

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