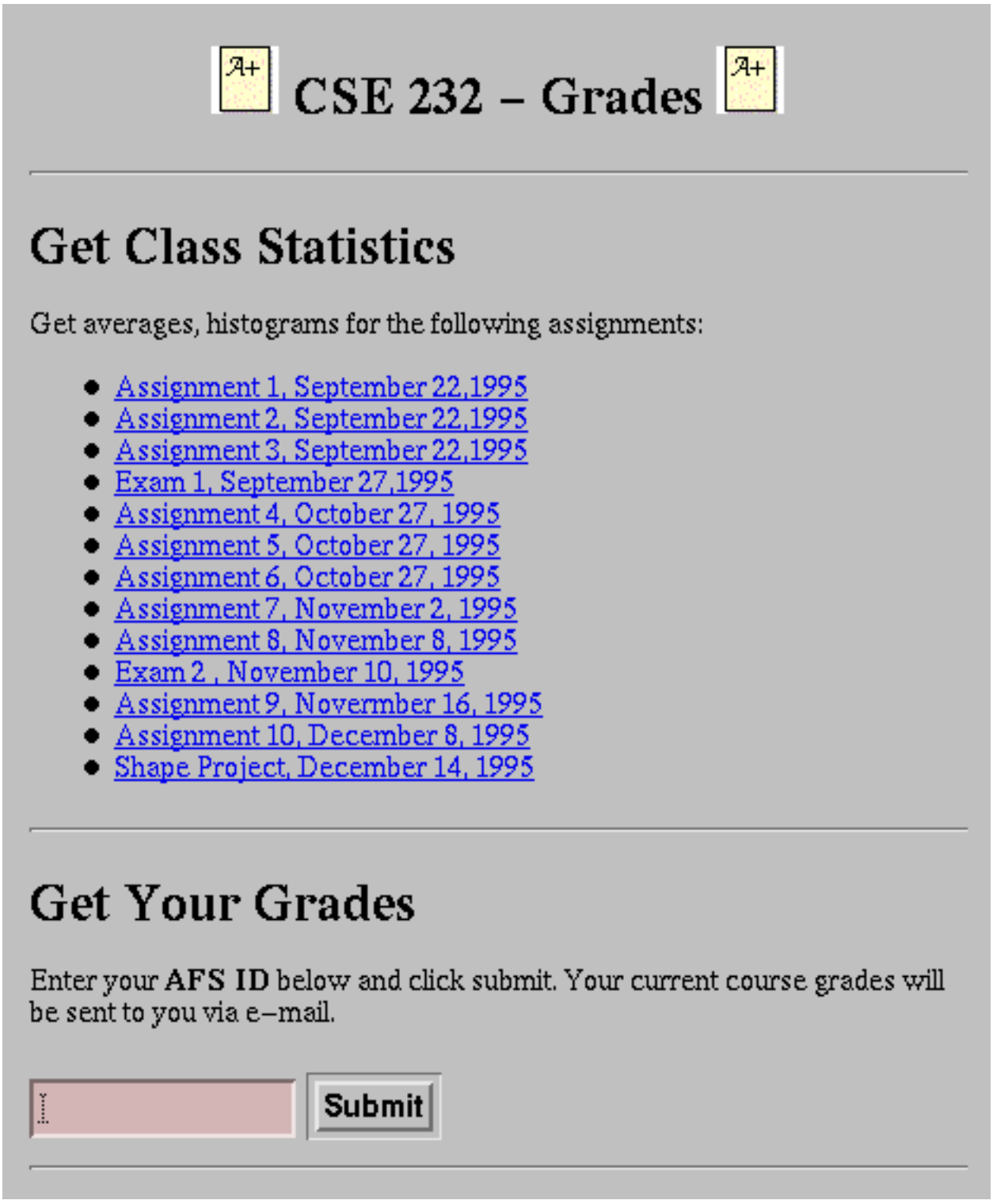

Figure 4: Interactive grade retrieval form

Figure 3: More hyperlinks to resources located on the Web

Course Description:

Top–down analysis, structured programming, and a discussion of the Unix operating system. Basic analysis of algorithms, algorithm development, implementation and debugging and testing of programs. Students will write several programs in the "C" language to learn the concepts that are taught and to acquire experience in solving problems. (ABET description)

Class Information

These icons will appear at the bottom of every CSE 232 page, use them to jump around quickly.

-  CSE 232 Home

  Will bring you back to this page.

-  News

  Up to the minute news about the class on newsgroup nd.courses.cse232

-  Lectures

  Get information about what happen during lectures.

-  Homework

  Homework handouts, due dates and solutions.

Figure 2: Course Description (goals) and links to more resources

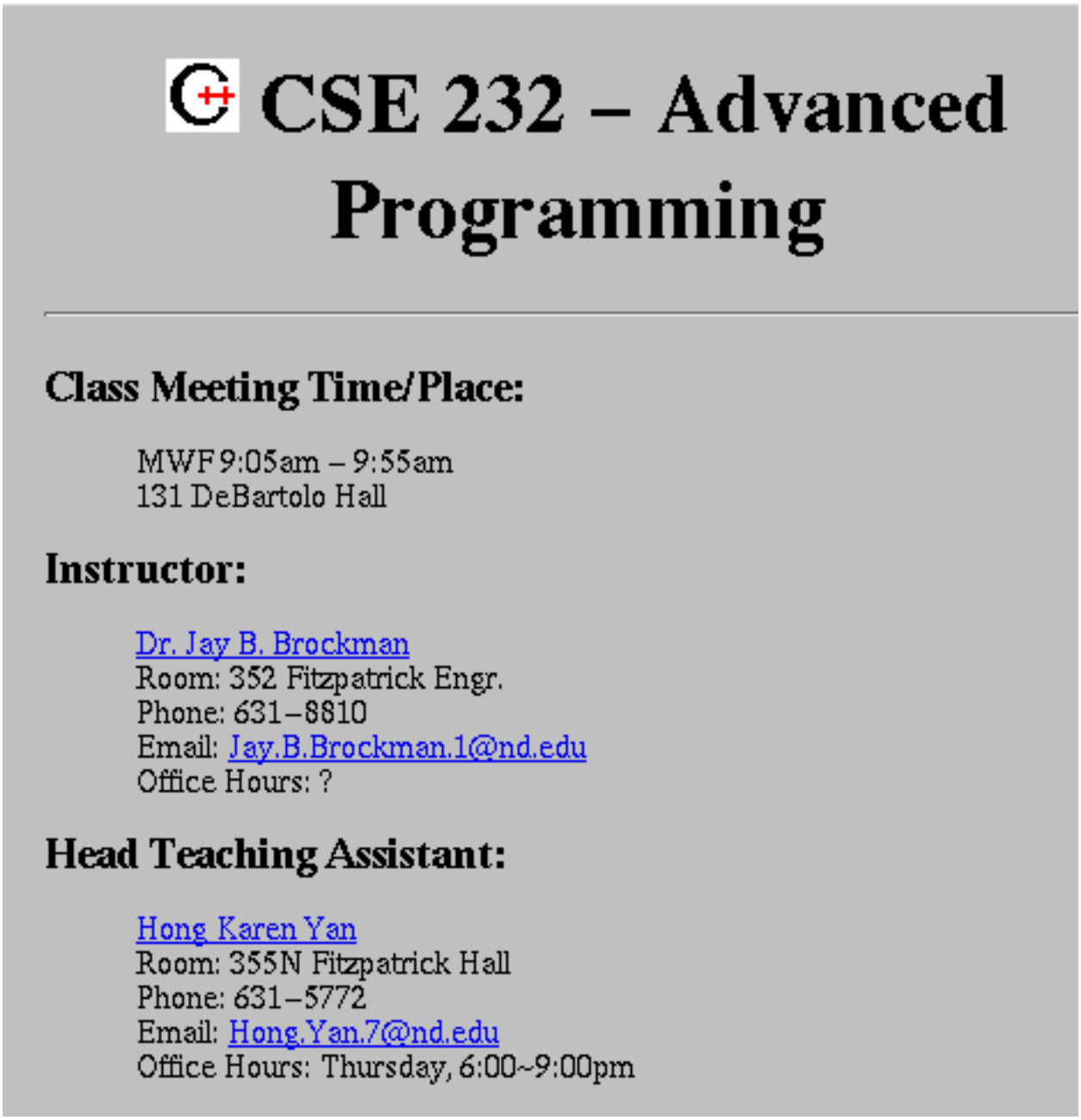

Figure 1: Important class information included on the class homepage

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Born in Flushing, New York, John J. Uhran received his B.S.E.E. at Manhattan College, and M.S.E.E and Ph.D. at Purdue University. His industrial work experience has included Hazeltine Crop., Bell Telephone Laboratories, NASA, Allied Bendix and MIT Lincoln Laboratory. He taught classes at Purdue University as a graduate assistant and instructor. Since 1966 he has been on the Faculty of the University of Notre Dame where he is presently a Professor and Associate Dean. His work interests include the field of communications, EDA tools, robotics, and neural networks. From 1970-90 he was an Associate Editor of the Transactions on Communications and was a member of the Society Editorial Board as well as a member of the Communications Theory Administrative Committee. Over the years he has organized a number of sessions for the ICC, NTC, GLOBECOM, MILCOM and SMC conferences and has participated in many of these with contributions. Also, he has offered a number of continuing education and short courses. Professor Uhran is currently Chair-Elect of the ASEE Zone II.

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Desney S. Tan

Desney S. Tan was born in the Republic of Singapore in 1976. He is currently working toward a B.S. in Computer Engineering at the University of Notre Dame, with expected graduation in May 1996. Mr. Tan has been named a Notre Dame Scholar and is a member of Tau Beta Pi (the national Engineering Honor Society) and Eta Kappa Nu (the national Electrical Engineering Honor Society), as well as I.E.E.E and A.C.M. His research interests lie in the areas of artificial intelligence and robotics. After graduation, Mr. Tan plans to return to Singapore to serve in the military, after which he will pursue a graduate degree.

Robert J. Szczerba

Robert J. Szczerba was born in Rochester, New York in 1968. He received his B.S.E.E. and M.S.E.E. from the University of Notre Dame in 1990 and 1993 respectively, with a concentration in Computer Engineering. He is currently a doctoral candidate at Notre Dame in the Department of Computer Science and Engineering, with an expected graduation date of May, 1996. During his time at Notre Dame, Mr. Szczerba was named a Notre Dame Scholar and awarded the William D. Mensch Fellowship for Excellence in Computer Science and Engineering. His research interests are in the areas of parallel and sequential algorithm design, artificial intelligence, computational geometry, and autonomous robotics.After graduation, Mr. Szczerba plans to pursue a tenure-track position in academia. Mr. Szczerba is also a student member of the I.E.E.E and the A.C.M.

Table 1: Comparisons of Modes of Communication in Education

	Real Time	Archivable	Unobtrusive	Exclusive	Extensible
in-person	XXX			XXX	
telephone	XXX				
e-mail		XXX	XXX		
newsgroups		XXX	XXX		
MUDs/MOOs	XXX	XXX	XXX	XXX	XXX
HTML/VRML	XXX	XXX	XXX	XXX	XXX

At the University of Notre Dame, we are currently implementing, while constantly developing, this new state-of-the-art electronic classroom. We do this in the hope of utilizing our resource base to provide for a productive and complete education. Much work has yet to be done. We hold the future in our hands; we may decide to ride the information wave, using it to its fullest potential, or we may choose to allow it to race past us, never to be seen again. May the latter never be our fate.

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language for describing multi-participant interactive simulations -- virtual worlds networked via the internet and hyperlinked with the World Wide Web [1]. Using this language, three-dimensional virtual worlds could be built where all barriers to interaction would be removed and the sharing of information could be done creatively, thus stimulating thought and further perfecting the education process.

4. Conclusions

In any group, communication between its members determines how well the group functions. This is true of communities of any size. Different tools are appropriate for different types of communications. With the coming of the information revolution, it was found that the traditional means of education (where students and professors met in person to transmit any information) could be greatly enhanced through the use of electronic media, e-mail for example. For the first time ever, professors could archive information which was transmitted and later retrieve letters in order to access the class and students could keep copies of answers to their questions; questions which were asked and replied unobtrusively, tastefully, whether in a private or public manner. This technology is great, but as we are quickly discovering, has its shortcomings. Despite its flexibility, e-mail is not entirely sufficient for all the types of communication which is required in education. Time dependant information, for example, and round table discussions, are two examples of applications which are not well-served by electronic mail. Newsgroups, an extension of e-mail, displayed similar problems.

Recently, with the creation of MUDs and MOOs, as well as the development of HTML and VRML, we are able to create real-time applications which greatly enhance the education process. These applications allow for the exclusive selection of membership and entry permissions as well as an environment where unobtrusive questions may be asked. These questions would not be directed at any specific person and would be open for productive discussion. The systems are also capable of archiving everything done on them for future reference. A comparison of current tools which have been implemented is illustrated in *Table 1*. These systems are by no means complete and are continually being upgraded and extended.

ask each other questions non-intrusively, and converse with other students and professors, who happen to be on, in real-time. Since the system maintains a log of everything which is said or done in a "room," discussions are archived and may be cited at a later date. Objects in the MOO, either automatically or at the behest of a user, may direct a user's client program to present files for viewing or editing, display a Web page, play a recorded sound, or do just about anything else. Slide shows are also a potential application of this mechanism. These objects can be passed around, pointed at, or written on, to facilitate discussions about them.

MOOs provide metaphors of real life (or virtual life). People and things exist in a place and one interacts with an object as one would in real life. This creates an interesting context for solving problems and simulating real-life situations. Even the spatial metaphor is used in constructing a MOO. Professors and students could easily create an environment which stimulates thought and discussion (anywhere from a classroom building type design, to a high-tech laboratory, or even a mountain resort). At this point, the potential and possibilities to develop MUDs and MOOs in useful educational tools seem endless [11].

Technology now allows us to place interactive applications on the Web with relative ease. Experiments and simulations, for example, may be easily created and reproduced, which further enrich the students' education. These techniques have been implemented with such applications as the prototype HotJava and Netscape 2.0 browsers, but has yet to be utilized in a systematic manner for classroom activities. These browsers build on the browsing techniques established by Mosaic(tm) and expands then by implementing the capability to add arbitrary behavior, which transforms static data into dynamic applications.

With the new browsers, enhanced HTML functionality now allows interactive applications to be executed from within the browser itself. The implications and potential uses of this are profound. Students are able to perform hands-on experiments which are otherwise not usually possible to perform. Dangerous experiments (those dealing with massive equipment or hazardous materials, for example) may now be simulated in a safe and reproducible manner. Making a mistake will not hurt students, but in fact allow them to learn and grow with the experience [10].

All these applications for the Web as an education tool may soon be tied together through the use of VRML (Virtual Reality Modeling Language), which is intended to be a

them presented on Web browsers already exist and are continually being improved. In these gateways, question files are created using an extended version of HTML, which includes additional tags invented to mark up various parts of the questions in various ways. Of course, regular HTML is still available so questions may include the embedded graphics and hypertext links.

The functionality of the gateways allows the tutorial writer to provide responses that depend in fairly complex ways on the answers provided by the student. This ranges from a “correct” or “incorrect” response, to one which actually depends on the answer which was provided, perhaps explaining why the answer was correct or incorrect. Incremental hints may also be provided. These could be hypertext links within the question itself, or incremental hints revealed one at a time at the request of the user. Currently, most gateways support simple multiple choice, true-false, and single-numeric or algebraic-expression answer questions. They provide a consistent interface to questions of the same type. This removes concerns with some of the details of implementation; for example, creating and upkeeping a form. It also maintains all possible responses in a simple source file; parsing and selection is all handled very neatly by the gateways [9].

Also, in the area of newgroups and interactive collaboration, MUDs (Multi-User Dungeons or Dimensions) and MOOs (MUD, Object Oriented) are very useful. These are network accessible, multi-user, programmable, interactive systems well suited to the construction of adventure games, conferencing systems, and other collaborative software. Their most common uses are as multi-participant, low-bandwidth virtual realities. MOOs, in particular, offer every participant the opportunity to construct spaces and objects and to write code that in some way augments or increases the functionality with these virtual spaces. MOOs are therefore constructed social spaces in a dynamic process of continual evolution -- the perfect virtual campuses for educational activities [4].

A MOO, like the Web, coordinates the efforts of many people to support collaborative projects over a network. A user can see what others are doing simply by “looking” at them to see what they are carrying -- notepads with “to-do” lists on them, reports of bugs they are currently fixing, or the progress reports of projects they are working on. By occasionally announcing briefly what they are doing, students keep others appraised of their progress. For many actions, these announcements happen automatically. Students and professors also

Homework assignments are also placed on the Web. It is no longer necessary for the professor to distribute hard copies of assignments in class; nor do students have to worry about losing the loose leaf of paper on which a large percentage of their grade resides. Students simply look on the Web for homework assignments and even the answers to previous ones.

Newgroups are another traditional resource utilized on the Web. Local and global newsgroups are areas in which students and professors alike may post questions and responses to questions which have previously been asked. This electronic question and answer bulletin board allows students and professors and, in some cases, professionals in industry to communicate interactively in an efficient and productive manner. It promotes participation and enthusiasm among students and gives professors a chance to evaluate the progress of the class as a whole as well as of individual students. The newgroups, therefore, serve as large pools of information where questions are answered very quickly from many different perspectives [5].

3. The World Wide Web in the Electronic Classrooms of Tomorrow

The World Wide Web is currently very under-utilized and its potential remains largely untapped. In this section, we will present the next step that must be taken in order to tap into the vast resources possessed by the Web and to fully utilize its potential in an efficient and productive manner. We move from a largely static educational environment to one which is highly dynamic and which is bounded only by the imagination.

In the electronic classroom of the future, the professor may set up a system of interactive assignments whereby students are required to do research and answer a set of questions relating to information found on the Web. Students would navigate the Web looking for answers and answering questions to which they will immediately be given correct answers. Students no longer have to wait days, sometimes weeks, for hand graded assignments to be returned. Now, they may instantly see exactly what they have done wrong and may immediately make appropriate corrections.

Interactive homework is becoming very popular among educators of tertiary institutions. “*Tutorial gateways*” that facilitate the creation of tutorial style questions and have

als available -- not only hypertext, but also pictures, graphs, and even on-line movies [2, 6].

Course information is now easily available at the touch of a button. Information about class meeting times and places are very accessible (*see Figure 1*). Professors and teaching assistants place their office hours and locations where it will be seen. Links to their personal homepages may also be included to allow the students to learn more about them and their academic interests in a convenient fashion. The goals and objectives of the course are also carefully laid out and well stated so that students understand why they are taking the class, how it will benefit them, and what is expected of them (*see Figures 2 and 3*). Along with this, grading information, students' grades and related statistics, and other rules of the class are also included (*see Figure 4*).

The administrative information which is placed on the Web is useful, but not crucial in realizing the potential of the Web in education. The first step in moving closer to converting the raw potential into a powerful tool lies in placing existing materials on the Web, thus making them easily accessible to the student.

Chalkboards and whiteboards are nearly obsolete in the electronic classrooms of today. Educators are moving from the slow and tedious process of writing notes on a dusty chalkboard while they speak, to class lectures based on slides created using a wide variety of presentation software. These slides are converted into transparencies and presented with the use of overhead projectors, or simply piped through multimedia equipment found in many of the new, well-facilitated calssrooms. This system of preparing notes allows the professor to spend less time on writing and more time on explaining the material.

By placing these materials on the Web before they are used in class, the professor allows the students to get a general overview of the material to be covered in class. Students are able to come into class with a clear idea of what to expect and, as a result, are much more adept at listening and understanding. Utilizing this technology also means that the student spends less time writing and more time listening and understanding, as notes (or at least an outline) are easily available both before and after class. It is still beneficial for students to jot notes down, but this is only to remind themselves of the key points which were made in class; points which they will later review. Additional reading material not available in the text (perhaps a text will not even be necessary) is also be placed on the Web for easy access [2].

processor (or desktop layout tool). This was developed in conjunction with CERN's hypertext documentation system. The Web was initially conceived of in order to facilitate communication and collaboration between individuals (or groups of individuals) working on specific projects. It was a place where one could interactively browse through and edit work done by others [12].

As it grew and was placed on the Internet, the Web 'ran away.' It was still in the early stages of development and many wrinkles had not been ironed out. In the process of being moved from a very closed and controlled system at CERN to one which was in the process of unmanageably exploding in size and potential, the Web lost much of its functionality and purpose. It was quickly embraced as an application which possessed not only *hypertext* (words or phrases in the document that can be chosen and which cause another document to be retrieved and displayed), but also graphic capabilities. This Web of color images and hypertext became used mainly for entertainment and advertisement. The dynamic potential of the Web was neglected for the passive "surfing" experience which the multimedia experience created.

Before the creation of the Web, people used computers to create paper. With the Web and its virtually unlimited potential, pagination is no longer necessary and hardcopy is fast becoming obsolete. This change is like the one which came about with the invention of the printing press. Like the change to paper publishing, its impact and ramifications has and will continue to affect many domains. Educators are fast realizing that it is becoming more difficult to provide a competitive education without the Web [6].

2. The World Wide Web in Today's Electronic Classroom

The World Wide Web is particularly well suited as a medium for the electronic classroom. In the current system, professors place course outlines, class notes, and other class related materials on the Web. This serves to enhance in-class activities by giving students full control and flexibility of their learning through convenient access to course material. The course *homepage* serves as a jumping point to resources on the Web pertaining to the particular class. It acts as the 'contents' page which students use to find desired resources. Through frequent repetition, students reinforce ideas and concepts with the various materi-

The World Wide Web:
An Interactive Educational Environment

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Abstract

As we race toward the 21st century on the "information superhighway", we find ourselves more and more tangled in the massive labyrinth of information which lays itself at our feet. Many developments have been made recently, but none has grown as quickly or has had as profound an impact as the *World Wide Web* (WWW or Web). We are presented with two options: we can sit back and watch as the information available grows and eventually engulfs us, or we can take the Web, nurture it and use it to our advantage. Internet-based resources have long been of interest to the academic community. Electronic-mail and multimedia presentations have been increasingly embraced by educators at all levels. But now, with the growing complexity and efficiency of the internet, much more may be done to expand the student resource base, and thus provide a more productive and complete education for the student.

In this paper, we will review current education techniques which utilize the internet, and more specifically the World Wide Web, including the use of homepages as information repositories, as well as e-mail and newsgroups. We will then propose several improvements to the current system which transform the static use of the Web into a dynamic domain which facilitates creative thought and understanding. Among the new applications we propose are interactive homework assignments as well as greater communication through the expanded development and use of *Multi-User Dungeons or Dimensions* (MUDs), *MUD Object Oriented* (MOO), *HyperText Markup Language* (HTML) and *Virtual Reality Modeling Language* (VRML) [1, 2, 3, 4, 5, 6].

1. The World Wide Web: Where it All Started

In order to truly appreciate the potential and ramifications of the Web, one must be familiar with its history, its creation, and its development. What we now know as the World Wide Web was introduced in 1989 at *CERN* (Counseil Europeen pour la Recherche Nucleaire), the European Particle Physics Laboratory in Geneva, by Tim Berners Lee, a networking expert, and Robert Cailliau, a documentalist. The original purpose of this project was to create a cooperative work tool, an application which could act as both a browser and word