CHIP: Computerized Homework in Physics

V. K. Saxena, H. Nakanishi, E. I. Shibata, D. Elmore, and D. Bortoletto
Department of Physics
Purdue University
West Lafayette, IN 47907
saxena@physics.purdue.edu

Abstract
The Department of Physics at Purdue University in West Lafayette is using a software system called CHIP (Computerized Homework in Physics) to grade homework in two large enrollment physics courses: PHYS 152 (calculus-based mechanics; recitation and laboratory) and PHYS 241 (electricity, magnetism, and optics; recitation). In spring 1998 there are about 3000 student accounts on CHIP; during some weekday nights over 1000 students are working homework on CHIP simultaneously and generating over 50,000 hits on the CHIP server. Students access CHIP through a Web browser, such as Netscape. By using a random number keyed on selected characters of a student's CHIP login name, homework problems can be programmed to have numerical answers which are unique for each student. Students may submit answers to several parts of a question at once for grading, and credit for correct responses is entered into an integrated gradebook. Within a few seconds students know whether their answers are correct. Before CHIP (and its predecessor), the homework sets were only partially graded or marked as handed in without grading, resulting in many students working very few of the homework problems correctly. With CHIP, typically 98% of the students work all the homework problems. Score normalization is no longer necessary.

Introduction
In the traditional methods used for physics recitation classes, the students are required to submit hand-written solutions to the homework problems, which then require a great deal of time on the part of the graduate teaching assistants (GTAs) to grade. For courses with large enrollments, this poses a very serious problem. For example, our first year mechanics course for engineering students has a typical enrollment of around 1300 students in the spring semester. With about 40 students in each recitation section and a GTA typically responsible for three such sections, most of these assignments (about 30,000 worked problems per semester) are never graded. Often this leads the students to believe that doing homework assignments is not a necessary requirement. In fact, in physics or any other scientific discipline, solving the homework problems constitutes an essential part of the learning process.

Besides the reluctance of the students to do the homework assignments and the somewhat limited time available to the GTAs for grading them, the traditional approach has another unsatisfactory outcome. Different GTAs teaching different recitation sections of the same course often have widely varying grading policies. This leads to discrepancies and abnormal distribution of recitation scores and eventually to student dissatisfaction. It generally requires normalization of recitation scores among the different sections.

The drawbacks of the traditional handling of the homework assignments led us to look for possible ways to give incentives to the students for doing their homework assignments and, at the same time, free some time for the GTAs who would otherwise need it for grading them. The search led us first to a World Wide Web-based system called CyberProf. Three undergraduate and two graduate students coded the approximately 500 homework problems during the summer. Armed with our experiences with CyberProf, we adopted another Web-based system developed by Dennis Kane and Gary Gladding of the Department of Physics at University of Illinois, Urbana-Champaign, in the spring of 1998. The core of this software is based on less than 1000 lines of code written in Perl, making it highly maintainable. It had been proven to function well in courses similar to ours at the University of Illinois.

After some additions and modifications for our use, we have renamed this new system CHIP (Computerized Homework in Physics). CHIP is being used for two large enrollment courses. For Physics 152 (first year calculus-based mechanics course), it has been used for recitations as well as prelab questions. For the other course, Physics 241 (calculus-based electricity and magnetism), only recitation is being covered by CHIP.

In the next section we describe the main features of CHIP, including its structure and the record-keeping procedures. Following the description, we discuss some of the additions we have made to the original software to provide some helpful features to the students and instructors. In the last section we discuss the merits of this computerized homework system, along with some recently collected statistics from a survey of students on the effectiveness of CHIP. We observe that computerized homework is definitely an enhancement in the education and learning process of our students.

Description of CHIP
CHIP is essentially a collection of CGI (Common Gateway Interface) scripts written in Perl which are accessed through the World Wide Web using any browser, such as Netscape or Internet Explorer. It consists of several components: (a) CGI scripts to handle presentation and scoring of the assignments, (b) CGI scripts that handle administration such as account and record keeping and statistics generation (called the *gradebook*), (c) homework problems themselves, (d) grade and student identification (SID) records,

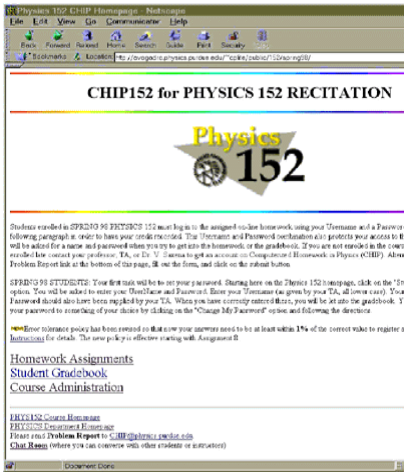
and (e) the public interface (static Web pages, problem reporting mechanism, chat room, etc.). Since it is written in Perl, it is highly portable, allowing its operation on almost any platform. Currently, we are running CHIP on a Pentium Pro-based PC with the FreeBSD operating system (a freely available version of Unix). In addition, since it does not use any Java codes which would need to execute on the user's local machine, it generates very light network traffic and does not require much local computing capability. For high-volume applications, such as the homework grading for large enrollment courses, the light load it places on the network is especially important.

Access to CHIP is password protected for different classes of users. *Students* can access only the homework assignment pages, i.e., those where they work on the homework problems and check their own grades. The *instructors* (professors and GTAs) of the course have access to the homework assignments and the Instructor's Gradebook, enabling them to check the homework assignments and the grades for their students, as well as to correct any information such as the identification information and homework scores. Editing of the codes for the homework is intended to be the function of another class called the *developers*. A privileged class called *directors* have all of the above access in addition to the Director's Gradebook which allows for the overall course administration such as creation of accounts, changing of passwords, defining sections, etc. All these functions are accessible directly through a Web browser. However, since CHIP uses plain text files for all problem codes, records, and the executable programs, it is possible to edit the appropriate files directly if that is more convenient. This is an advantage as standard and familiar editors with powerful features can be used. However, as the number of the courses using CHIP grows, the number of record files increases (each student will have one file for each problem attempted in addition to other files required for proper record keeping), and there will be a point where a proper database format will be desirable.

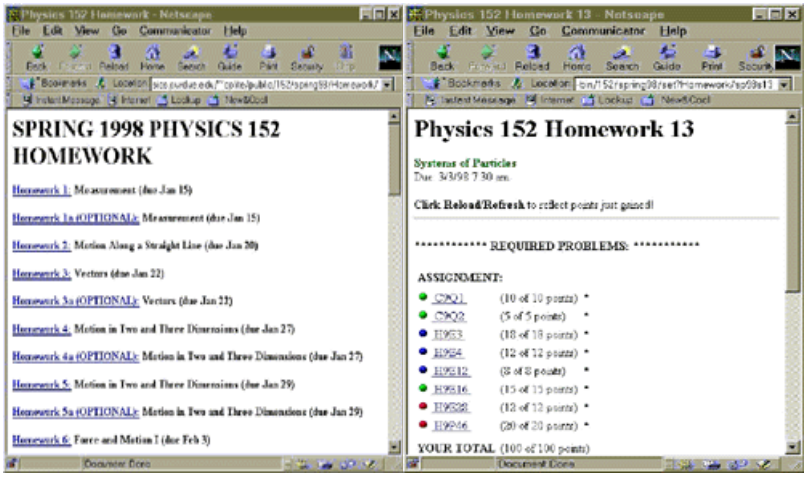
Below we show some of the screen shots of the Web pages served at different stages for different classes of users. The first is the publicly accessible CHIP152 homepage, the starting point for entry into the CHIP for Physics 152 homework. The reader can follow along by directing a browser to the following URL:

http://www.physics.purdue.edu/chip152/

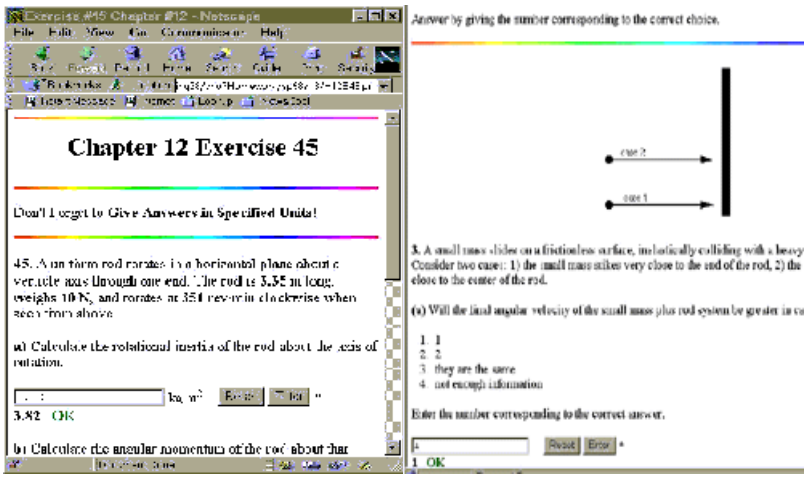
and using the guest account with user-name *guest*, password *guest*.



Students then proceed to click on the Homework Assignments choice (leading to the list of assignments and eventually to individual problems) or the Student Gradebook (showing their own score records). Entry into these pages is via authentication by username and password. The username is used also to construct individualized problems as described below. Part of the List of Assignments page is shown on the left below, and part of a particular Assignment page selected from the list is shown to the right.

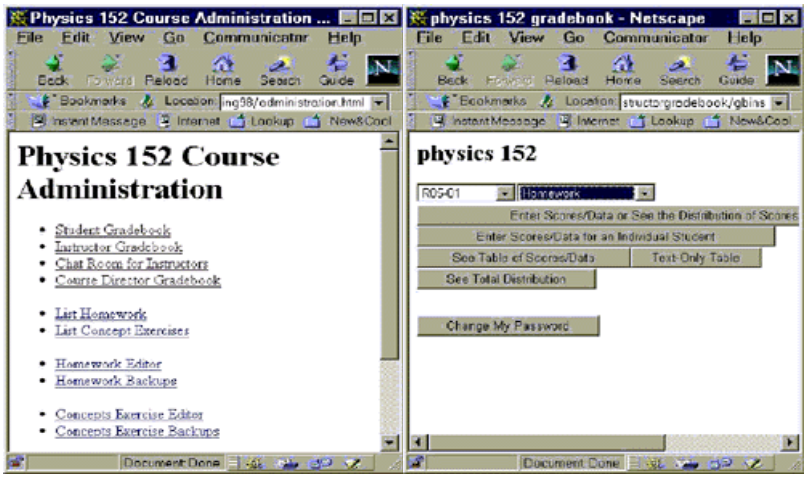


The assignments can have conceptual as well as numerical questions and problems. Currently CHIP only accepts numerical answers; thus, multiple choice problems are labeled by numbers and treated as if they were numerical problems. Both types of problems are illustrated below. For some of the more difficult problems, on-screen help or a hint can be coded along with the problem and accessed through a button provided on the problem page.



Using pseudo random numbers keyed to the username for the input parameters, each numerical problem is tailored to the specific user and only accepts the corresponding unique numerical answer. The acceptable error bounds can be specified for each question individually, with a default of 1%. The problem page is a simple HTML form and thus any or all of the numerical answers for problems with several parts can be submitted separately or at once, and the grading is essentially instantaneous. Each assignment can have as many deadlines for submission of answers as desired, with specified reductions in scores for late submissions of varying degrees. Most students keep on trying a problem until they are told by CHIP that they have the correct answer.

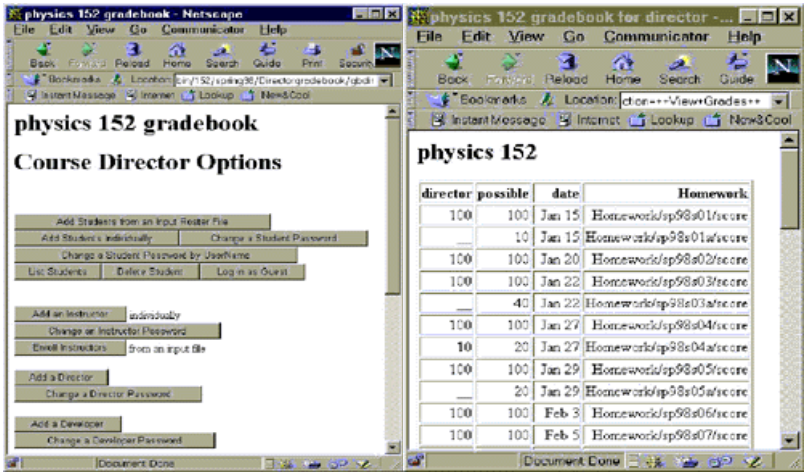
Shown next is the Course Administration page, the entry point for the instructors to check their students' performances, for the developers to edit or create new problems, or for the directors to add accounts, etc. To the right, the Instructor Gradebook top page is shown, indicating some of the functions which are standard in CHIP.



Instructors can edit the roster information such as the students' names, student identification numbers, and recitation section assignments, as well as grade information such as the scores for particular homework sets. We require all GTAs to work on the same problems well in advance of the students' deadlines. To keep their records, we assign them to a special section. Thus, we have disabled all instructors except those specially designated (normally professors in charge) from editing entries in this special section.

Next, part of the Director's Gradebook main page is shown to the left below. This page, accessible only to the directors, is used for overall course administration such as enrollment of all categories of users and control of their passwords and other records. It is also used for generating statistics and many other standard administrative requirements. If other features of the course such as examination or laboratory scores are to be integrated into CHIP, it will also be done through the Director's Gradebook.

To the right of the Director's Gradebook, we show a typical page from the Student's Gradebook where a student can check his or her homework grades. In this example, the student happens to be "director."



Local Enhancements

At Purdue, we have made some enhancements to the original system created by Dennis Kane. Some of these deal with administrative issues, while others directly affect the students. Enhancements that improve the system for Purdue students are these:

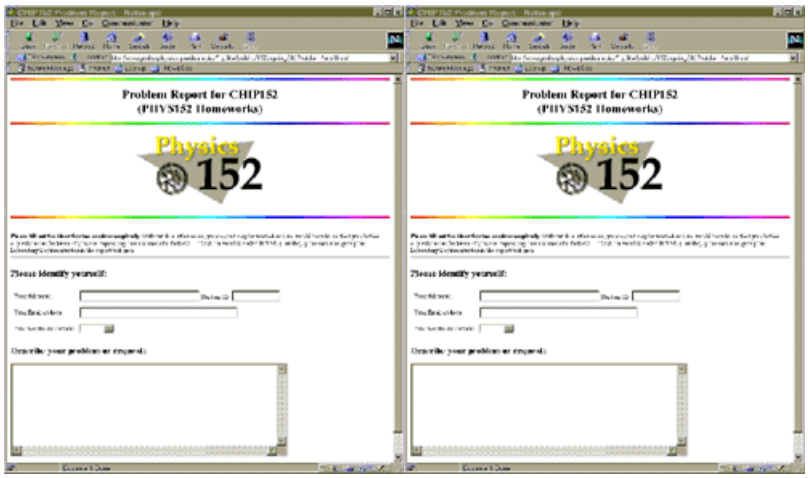
1. Printing of entire assignments with the numerical values specific to the user,
2. Simple, entirely HTML-based Chat Room,
3. Easily accessible Problem Reports, and
4. Tighter integration with course home pages and other related resources.

While the students can easily print any particular Web page (such as a problem they are working on) from the browser by clicking on the print button on the browser interface, this only prints a single problem, and whatever fonts are used by the browser will be used by the printer, typically wasting a lot of paper. Thus a script which allows the printing of a whole set at a time using small fonts is helpful to the students, particularly for those who wish to take the printout to a different location and work on it away from a computer.

Chat rooms are also a feature heavily used by our students, who are encouraged to work collaboratively. A place where they can communicate with each other over the Web while they are working on the problems in another window is very useful to them. The Chat Rooms are typically quite busy until early morning hours before the due dates of each assignment. Usually there are a few students who are willing to help a host of others seeking help. The instructors have their own area to display their statements so that the students will know that they are looking at the instructors' comments, not another student's. These areas are entered via user authentication and the instructors can and do keep it under control, occasionally disabling some abusers from further participation.

We have also added a Problem Report feature to CHIP. Through this the students can report any problem they face during the use of CHIP: problems with logins and passwords, physics questions about the homework problems, or any other related inquiry. This report form is directly sent to the CHIP staff, who can then reply to the student by e-mail. Salient information to identify the student, section and course are required. The Report will not go out unless such information fields are completed.

Below, we give screen shots of the Problem Report (left) and the Chat Room (Right).



Administrative enhancements include the creation of a class of instructors in between the ordinary instructor and directors in privileges. This new class of instructors (normally professors in charge of the courses) has the ability to assume the identity of any student and see the problems and his or her recorded answers exactly as the student sees them. This ability is especially useful when students report improbable behaviors of CHIP or its Gradebook.

Discussion

CHIP has been a great success at Purdue this semester. In a recent student survey, a great majority (77%) of the students who participated in the survey (979 students out of 1180 enrolled in Physics 152) prefer CHIP to the old method of manual grading of a randomly selected problem. In addition, CHIP is viewed as the most effective tool for learning physics by the largest number of students (36%), even ahead of the textbook (32%), and far ahead of the lecture or the lab. The features of CHIP students like best are unlimited number of attempts (52%) and instant feedback (38%), while they dislike most the inability of CHIP to tell them exactly which part of their work is wrong (74%). Forty-seven per cent of the respondents agree or strongly agree that CHIP helps them improve problem-solving skills, while only 18% disagree. Although a thorough educational assessment is still lacking, we are confident that the approach represented by CHIP has a great potential for rejuvenating elementary physics instruction in large enrollment courses.

One must be careful in selecting exactly which software to use, however. The software we used initially caused constant disruptions and student dissatisfaction. There are a number of Web-based homework grading software packages available today. Some are Java-based, while others are entirely CGI-based. Some are freeware; others are commercial. Some are locally maintainable while others are essentially black boxes over which one has no control. Any institution contemplating the use of a Web-based learning system will be well advised to make an in-depth survey of the available software before adopting one. Having stated this, we are happy to report our satisfaction with CHIP, particularly with its simplicity and maintainability, two of the most notable strengths of this software.

CHIP does have weaknesses. For example, it lacks some features which are standard on some similar software: limiting the number of attempts, measuring and recording the response times, randomizing multiple choice questions, proper handling of questions with multiple correct answers, and inclusion of units as part of the answers. Most of these features could, however, be incorporated in the future with a moderate level of Perl programming expertise, a skill typically available in a large science department such as ours. A deeper shortcoming which needs to be corrected for larger scale use (6,000-9,000 accounts) concerns CHIP's use of the file system structure in place of a true database. Though the disk space requirement resulting from this problem could be easily circumvented

by simply adding more or larger disks, the resulting fragmentation of millions of files would eventually make data access inefficient.

One further concern with CHIP or any similar Web-based software is security. Currently all CHIP-related files (including grades and problems) are owned by the pseudo user ID of the Web server (or by its group) so that the CGI programs executed by the Web server can read from and write to them. Since anyone who has authorization to write a Web-server-executable CGI script could in principle read/write files owned by the Web server, we have a dedicated CHIP server machine (Pentium Pro PC with 256 MB RAM and 2 GB hard disk), inaccessible to general users. This solution may not be workable in a small department with very limited resources, although the cost of such a server is rapidly decreasing. Another security concern is the use of ordinary Web-server-based user authentication. Since such authentication schemes use unencrypted network traffic of usernames and passwords, they are vulnerable to eavesdroppers and hackers.

Both of these security shortcomings could be repaired, with a rewriting of the program into a properly configured client-server setup. In such a configuration, CHIP server software would serve as an intermediary between the Web server which requests read/write operations and the sensitive CHIP files as well as an agent to authenticate the user for access to these files. Since CHIP consists exclusively of human-readable Perl codes, this modification should not be beyond the scope of typical technical expertise available in a large science department, though there will surely be a substantial cost to such an upgrade in terms of person-hours. However, such an investment is a one-time effort and, in comparison with the GTA's time continually released by the use of CHIP, may be considered quite reasonable.

With this optimistic note, we conclude our description of the CHIP system. In short, it works well for us, and even its shortcomings are expected to be reparable at a reasonable cost. Its educational value appears to be substantial though a detailed, professional assessment is still lacking.