2006-2279: USING WEB-BASED HOMEWORK IN AN INTRODUCTORY ENGINEERING PHYSICS COURSE

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Using Web-based Homework in an Introductory Engineering Physics Course

Abstract

Working homework problems has always been an integral part of an introductory engineering physics class. Traditionally, the homework process has been an inefficient one which involved students writing solutions on paper, turning the papers in, instructors grading the papers, and returning the papers back to the students to provide for feedback and evaluation. This process is very time consuming for a large class, the resulting feedback is generally minimal, and it is difficult to control copying. This paper will discuss the issues, advantages, and disadvantages of a custom web-based homework system designed to replace the traditional paper-based homework system. This custom system implements most features found in other web-based systems such as creation and management of problem libraries, scheduling of assignments, presentation of the problems with randomly assigned parameters for each student, automatic grading, and providing statistics of results. In addition, this system addresses learning issues such as enhanced feedback, interactive help, documentation of the problem solving process, and the evaluation of the use and effectiveness of the system. Documentation and interaction is enhanced by allowing students to include their work in an online calculator/notes box associated with the homework so instructors can view the student's work on the problem and assist with questions. Interaction and feedback is enhanced with a link directly to a web-based discussion forum which allows students to quickly access questions and answers on the assignment. To encourage homework completion, the system allows for multiple due dates with increasing penalties the later the homework is finished. One of the disadvantages of a web-based system is that it does not typically require students to write out solutions in a clear and logical manner. This issue has been addressed by requiring students to maintain a portfolio of written solutions to all homework problems**.** Portfolios are periodically checked for completeness and have proven valuable in helping students develop better organization and work habits. Overall, the custom web-based homework system has been in general use since 2003 and has proven itself to be an efficient and effective learning and evaluation tool.

Background

We start first by investigating the issues involved in using a web-based online homework system in a large freshman level engineering physics class. A traditional system of paper based homework is labor intensive, time-consuming, highly dependent upon student motivation and integrity, and historically not very effective. With the proliferation of the availability of internet access and the maturation of tools for providing for personalized instruction and evaluation of every student, the use of an online homework capability seems to be a natural application for a class of this type. This leads to several general questions: What online homework systems are available and what is the theory and history of their development? What issues must be considered when implementing and utilizing such a system? What successes and problems have others encountered when using online homework systems in similar types of classes? What mix of traditional techniques with new tools provides the best results?

When considering replacing traditional methods with computer-based methods, is it important to consider if there are inherent differences caused by the different mediums. In looking at the issue of student performance on computer based tests versus paper tests, Bugbee (1996)[1] finds that students do at least as well on computer based tests as paper based, that they like computer based tests, and that they took more time to complete computer based tests than paper based, yet believed it saved time.

Implementation issues surrounding an online homework system are important factors to consider. Bonham, Titus, Beichner, and Martin (2000)[2] present many of implementation concerns. Every available system will have its own set of challenges and issues. The ideal system would be highly customizable, integrate seamlessly into an existing information infrastructure, and have an established database of questions available for use. Bonham lists 20 different online homework systems available from a variety of sources such as universities and book publishers. Based upon the frequency of appearance in this literature review, the WebAssign system (http://www.webassign.net) from North Carolina State University and the Computer-Assisted Personalized Approach (CAPA) system (http://www.lon-capa.org) developed at Michigan State are the two most prevalent systems.

The necessity of homework is derived from the need for students to apply and practice what they have learned in lectures or from their readings. One of the biggest challenges in the education of engineering students is encouraging them to practice these new applications of science and math. Such practice involves using basic problem solving skills and techniques to apply basic science concepts to a wide variety of problems.

Practice is a necessary component of working engineering problems. A sports analogy of this is watching someone demonstrate and play a sport and thinking that you can perform in the same manner with the same skill and efficiency. Practice and drill are very necessary components. Towards this goal, the Tang and Titus (2002)[3] study focuses on the challenge of increasing students' time on task. They conclude that a system such as WebAssign has a significant positive effect in this area because students get immediate feedback with tangible results (grades) and thus are much more challenged and motivated to complete assignments.

There are many potential benefits to using an online homework system. As Thoennessen and Harrison (1996)[4] suggest, automatic grading reduces the number of teaching assistants required for grading homework and/or frees time for more interactive contact with students. In addition, the instructors and assistants can be viewed as a helpers rather than graders or judges.

One of the distinct features and benefits of most online homework systems is the capability of providing each student will a personalized set of questions. This is usually done by establishing ranges of values for the various numbers used in the questions and randomly generating specific values for each student. This approach requires each student to work the problem with his/her unique values, thus eliminating the potential copying of solutions and answers that is prevalent when all students have the same exact problem.

Immediate feedback is perhaps the most important benefit of an online homework system. Hall et. al. (2004)[5] points out that online homework provides many opportunities for immediate feedback. Even with traditional homework, students have a very strong desire to compare their

answers with the "back-of-the-book" answers to determine if they have worked the problem in the correct manner. This leads to high student motivation to complete homework problems and is a major implicit benefit of an online homework system.

Cheating has always been a major issue in the assignment of traditional paper based homework. Students, when working together, tend to think that they understand everything being done as they work with another student or students on a homework problem, but since everyone is working the same problem, they tend to not execute all of the detailed steps. Online homework systems effectively combat this problem by forcing all students to work through their versions of the problems. The benefits of students working together are retained, while the practice and drill of each student working the problems is enforced.

Another concern cited throughout the literature is the use of trial and error as a solution methodology. Online homework systems use several strategies to defeat the usefulness of the trial and error approach. The number of tries can be restricted, students can be penalized for each try, or a minimum time period between tries can be enforced.

Issues of instructor proficiency in constructing quality problem sets must also be considered. Creating problem sets requires a thorough basic understanding of the principles being tested, an understanding of pedagogical methodologies to ensure that the homework reinforces the concepts being taught, and a high level of familiarity with the nuances of the tool being used.

Pascarella (2004)[6] presents another advantage of an online system – its ability to generate statistics about the difficulty of problems and the ability of educators to monitor and evaluate these statistics. Since all attempts and answers in an online homework system are stored in a central database, instructors can access this data to monitor the class' progress on assignments. Problems with solution errors or confusing wording can be spotted quickly based upon the lack of correct answers or an abnormally high number of attempts before obtaining the correct answer. Once identified, the problems can be corrected before many students access the problem for the first time. In addition, Thoennessen and Harrison (1996)[4] note that the ratio of incorrect responses to correct answers can be used as measure of difficulty of concepts, and this information can be used to adjust the material presented in lectures.

The capability of online homework to integrate multimedia components to provide additional instructional content and feedback is a benefit that does not have a counterpart in paper-based homework. Kortemeyer (2003)[7] notes that problems utilizing interactive multimedia have a dramatic positive impact on visual and constructivist learners.

While not part of existing systems, future online homework systems could look at collecting all details of the students' work, including basic equations, intermediate calculations, the flow of the solution, and even graphical sketches. The availability of this information to instructors would allow for even greater feedback potential as students have problems working through the solutions. In addition, the documentation of a complete solution rather than a final single answer would encourage students to organize their work in a clear and logical manner.

The correlation of homework performance to exam performance is a logical factor to investigate. Kortemeyer (2003)[7] provides a summary of pre/post-test instruments used for physics classes.

The most used seem to be the qualitative Force Concept Inventory and the quantitative Mechanical Baseline Test. Kortemeyer (2003)[7] also notes that there is also a wealth of information such as answer attempts, discussions, browsing of content material, and hint usage that is available and can be studied to analyze the interaction of students with the CAPA system.

Hall et. al. (2004)[5] and Thoennessen and Harrison (1996)[4] show that there is a strong correlation between test scores and homework scores for those who have low homework averages i.e. if a student does not do their homework they will not do well on exams. However, there is not a strong correlation between high homework scores and high exam scores. This can be explained by the fact that motivated students can and do work hard to complete all homework assignments utilizing all available means of assistance, but those same students do not possess enough of an understanding the concepts and efficiency of working the problems in order to achieve desirable results in a time and resource constrained situation such as an exam.

Cheng, Thacker, Cardenas, and Crouch (2004)[8] provide experimental data comparing the performance of four subgroups of physics students. The subgroups were the combinations of interactive engagement (IE) vs. non-interactive engagement (NIE) teaching methods and online homework (OHW) vs. ungraded homework (UHW). In all cases, OHW provided better results for students of all capabilities, regardless of the type of engagement.

Pascarella (2004)[9] takes a different research direction by studying indirect implications of online homework systems such as the changes in behaviors of different types of students. The study categorized the students into four groups based upon their style of problem-solving and then summarized the advantages and disadvantages of each homework approach relative to a particular style. In addition, the study generalizes and provides several suggestions for possibly improving the effectiveness of online homework for the various types of students.

Albertelli, Korkemeyer, Sakharuk, and Kashy (2003)[10] present a slightly different twist on the use of personalized, online homework. They use the CAPA system to generate many versions of the same quiz and give the quiz as a traditional paper quiz with the results entered via optical scanning of bubbles on an answer form. Their claim is that this approach did much more than discourage or inhibit students from copying or cheating on exams – it allowed them to make considerable use of quizzes as unannounced tasks at the end of lectures, thus resulting in a large decrease in absenteeism and correlating positively with student performance. In addition, they made use of this technology by allowing students to rework problems missed on exams for partial credit – thus turning the summative exam assessment into a formative assessment tool as well.

There does not seem to be a consensus in the literature on whether or not online homework can produce a measurable improvement in performance of students. Bonham, Beichner, and Deardorff (2001)[11] and Hassler et. al. (2004)[12] both find that student performance differences were not statistically significant. However, in the same study, Bonham states the greatest benefit of online homework was that it can free up personnel and monetary resources which can be devoted to other aspects of the course where they can make a greater difference. Another intrinsic benefit is that computers allow for a wider variety of questions that would not be possible on paper. On the other hand, there are no indications that the use of online homework leads to reduced performance. As previously discussed, many other benefits of the online

homework approach are well documented. This leads to the conclusion that the use of online homework is a valuable tool that should be implemented as part of an introductory engineering physics course.

Based upon the discussion and findings presented above, there are many avenues for further research. Does an online homework system improve learning as compared to the use of traditional paper-based homework? What type of feedback is the most effective for promoting good problem solving skills? Further research is warranted to determine if measurable improvements can be documented in specific environments. Many other areas can also be formally investigated to increase our understanding of the interrelationships of online homework and learning styles. New and improved methods of providing feedback and documenting and evaluating solution methods are also potential areas of investigation.

Bonham, Titus, Beichner, and Martin (2000)[2] summarize some potential areas of research that are natural extensions of web-based assessment and testing systems (WATS). One of these areas is large quantitative studies – WATS makes it easy to collect large amounts of data when the initial infrastructure is already in place. Another are would be studies with widely dispersed subjects – WATS provides a seamless way of distributing tests and surveys to anyone, anywhere and immediately collecting the data. A third area is the monitoring courses already using WATS – much can be learned about how students progress and utilize feedback by studying the detailed logs of an online homework system.

Finally, Bonham et. al. (2000)[2] list several practical suggestions to keep in mind when incorporating WATS as a research tool or as a topic of research. Among these suggestions are knowing how the students use the system, planning ahead, maintaining a good relationship with the system administrator, limited use of advanced features, minimizing interference with on-going classes, and being realistic about user authentication.

Philosophy

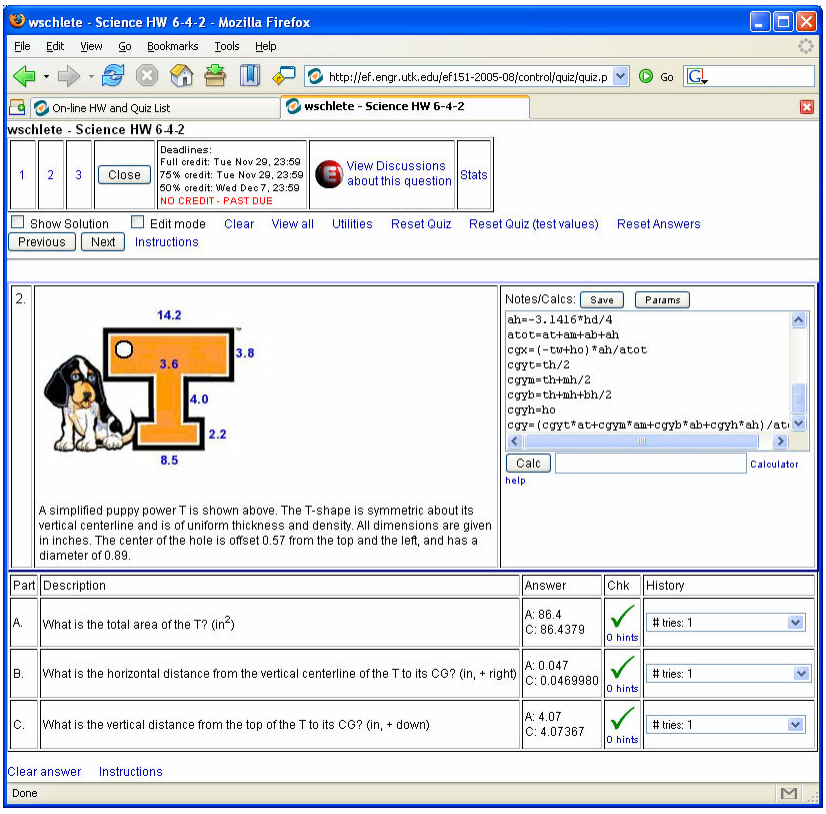
Working homework problems has always been an integral part of an introductory engineering physics class. It is our philosophy that this process is a critical one, and that the more opportunities students have to work problems, the better off they are – i.e. there is not a substitute for practice. Students learn by working problems, not by seeing problems worked. This idea, coupled with the philosophy that homeworks are learning tools and not evaluation tools, has influenced many of the implementation decisions we've made.

Implementation

The current system used for online homework in our engineering fundamentals classes is one that has been custom developed by the teaching faculty. Prior to the development of the system, many different alternatives were evaluated. The university's standard system – Blackboard – was not used because of our poor experiences with the system's availability and performance, its lack of flexibility in supporting numeric problems, and its inability to handle multi-section classes effectively. Other commercial systems were not considered as there was no significant funding for such a system. Free or low-cost solutions such as the CAPA system from Michigan State and the Webassign system from North Carolina State were also considered. They were not used

primarily because it appeared that these systems would be difficult to customize so that they could be integrated with our existing custom course management system. The availability of the necessary experience, expertise, and interest in developing a homework system customized for our philosophies and requirements was also a significant factor.

A single dual-cpu Redhat Linux based server provides course management (grades, notes, schedules, announcements) and homework functionality for approximately 1000 students taking engineering fundamentals classes. All server software is based on open-source applications – the Apache web-server, the MySQL database, and the PHP application scripting language. This configuration has proven to be very robust and surprisingly efficient. Students authenticate themselves via the university's LDAP server and can access the system from any standard web browser. Instructors develop problems via a web based interactive interface, defining required parameter ranges, graphics, text, and solutions.



The figure above shows a sample screen from a homework assignment. A single assignment can consist of multiple problems, each with multiple parts. When a student first accesses the assignment, the system generates the student's parameters for that assignment based upon predefined ranges and criteria. Each problem can have a graphic which is dynamically generated to display student-specific parameters as required. Parameters may also be included anywhere in the problem description.

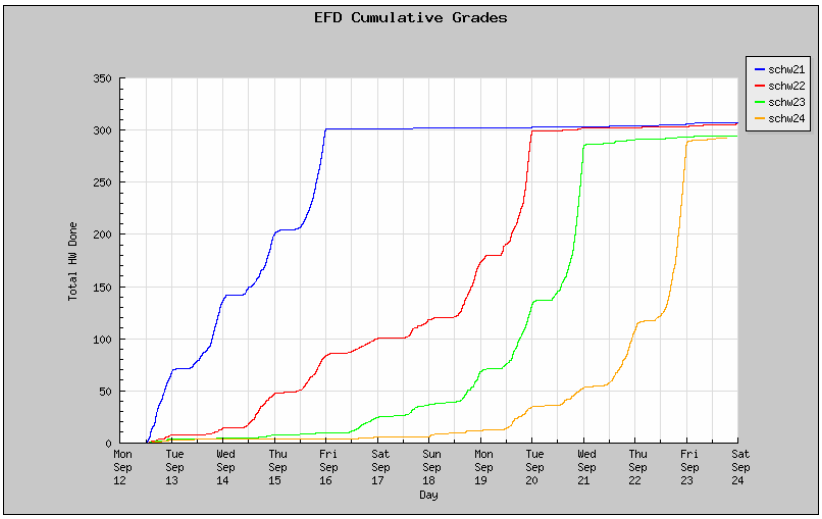
Although the system can limit the number of attempts for a problem, we have found that the best option is to allow the student to attempt the problem as many times as necessary to get the correct answer. Each attempt along with a timestamp is logged in the database. This data can be

viewed through the drop down box on the right. This enables students, faculty, and teaching assistants to see the detailed history of answers at any time. Tolerances for the correct answer can be set either in terms of a percentage or an absolute value. Recently a warning system was implemented if it appeared the student was guessing. The system simply checks the frequency of tries and if there is a large number of tries in a short period of time, the system will warn the student that it appears they are guessing and encourages them to get help. The system also automatically notifies the instructors if a significant amount of guessing is happening as this is often an indication of a problem with the homework.

A work area is available for the student to store their work online if desired. The work area utilizes Javascript capabilities of the web browser to provide a powerful calculator capability, as well as providing a means for students to document their work. The system is integrated with a discussion board which means students are only a single click away from asking questions and viewing discussions about any particular problem. A link to the discussion board coupled with a search engine is provided in each problem so students can quickly go to discussion on that particular problem. The discussion board is regularly monitored by faculty, graduate teaching assistants, and undergraduates specifically hired for that purpose. Thus, students can usually get an answer to their question within a few hours, even in evenings and on weekends. In addition, the integration of the discussion board and the online homeworks enables a link to be added to the discussion board so that faculty and teaching assistants can access a student's homework via one click. This provides a quick and efficient way of seeing what the student is doing and answering specific questions.

The system is completely flexible in how problems are presented. A standardized template is provided but at the lowest level the system utilizes HTML code, thus supporting virtually any type of formatting and graphics. Final answers can be required, or step-by-step answers can be used to help students learn as they go. Each answer is submitted independently and hints, if appropriate, can provide immediate feedback to the student if they are having trouble. In addition, the system supports multiple due dates for partial credit so that students are encouraged to work the problems and learn the material even if they are unable to complete the assignment for full credit. Typically homeworks are due two days after the material is covered, with 75% credit being awarded if the homework is completed by the end of the module, and 50% credit being awarded if the homework is completed by the end of the semester. For example, if a homework had 10 problems and the student completed 6 problems by the due date, 3 more problems by the end of the module, and the last problem by the end of the semester, the student would earn a $6(10)+0.75[3(10)]+0.5[1(10)]=87.5$ for that homework.

Statistics



The graph above represents the class' combined homework scores for four assignments plotted versus time. This graph clearly shows that students routinely wait until the evening before the homework is due no matter how much time they have to complete the assignment. Based on these results, we have moved up the homework due dates. We used to give about four days between when the material was covered and the homework was due. This was based on the philosophy that students would get a chance to try the problem and then have sufficient time to get help on problems they were stuck with. However, since students were not trying the problems, we have moved up the due date. The implementation of the partial credit system enabled students who were stuck to still have a chance of earning most of the points after getting help. This graph also is beneficial for a quick overview of the problems. The faculty can easily see if one problem is giving students trouble. They can look further into that problem to see what part is actually giving the difficulty, and address that part in either lecture or recitation.

A correlation of homework performance to exam performance confirms the obvious expectation that students who do not complete the homework assignments do not perform well on exams. However, at the other end of the spectrum, there is no strong correlation between completing homework assignments and doing well on exams. This can be attributed to the difference between homeworks and exams – homeworks are a learning tool, not an evaluation tool – they are not time constrained, allow multiple attempts, and they allow for students to get assistance.

Another interesting statistic that we have just started to investigate is that of homework attempts and efficiency. Since the system typically allows unlimited tries, most students can eventually get the correct answer to a problem. In fact, this goal of getting the correct answer even if it takes several attempts is a vital component of the system in that it encourages the student to stick with the problem and work through it until they get it correct. However, students who struggle with the problems on the homework usually struggle with working similar problems on exams where accuracy and the efficient use of time are critical. There is great potential here in looking at how homework performance relates to exam performance.

Portfolio Integration

As mentioned earlier, one of the disadvantages of online homework in general is that it does not require students to write out their work in a logical and organized manner. To address this issue we have taken the approach of requiring students to work their online homeworks on paper as they work towards the answers that they will submit online. The students then include these paper solutions in their class portfolio that is periodically checked for completeness. This approach worked well in encouraging students to write out their work, but it still did not give students feedback on the quality of their written solutions. Therefore, our current approach is to select random assignments, have students turn in their written solutions to those problems, and have our graduate assistants review these in detail. The grading of the written problem is primarily to provide feedback on format, methodology, clarity and completeness, and not to check the correctness of the work.

Issues

There have been surprisingly few difficulties with implementation of the system. Students learn the system very quickly and seem to appreciate the immediate feedback. The system has proved to be very robust, and able to handle many types of problems. The tolerance on the answer is usually set to 1%. Carelessness in rounding can cause students who worked the problem correctly to not get an answer close enough to the correct answer for the computer to give them credit. This can be frustrating to students, but a good way for students to learn the importance of carrying enough significant digits in their intermediate calculations and when numerical errors may be a problem (e.g. cancellation of terms). On the other hand, we have seen that an overemphasis on significant figures can frustrate students and cause them to spend more time fighting the system rather than learning the material.

The range of the random parameters has to be carefully chosen so that all combinations give solvable problems, meaningful answers, and truly make the student work the problem correctly. For example, we try to avoid combinations of numbers that would result in 45° angles for which the student could incorrectly use either sine or cosine but still get the correct answer. Another example is a dynamics problem involving two masses and pulleys. Originally there was a combination of parameters that resulted in the problem being static, for which the acceleration was the trivial answer of 0.0.

Future Work

Potential enhancements under consideration for improving the current system include implementing a Macromedia Flash-based user interface (the current method utilizes HTML forms), implementing an XML based scheme for defining problems (the current method is an interactive form that interfaces directly with the database), supporting the user entry of arbitrary units for answers (the current system supports only numerical answers), and allowing for freehand sketches and drawings as part of the student's stored notes for problems. With a database logging the details of hundreds of thousands of completed homeworks, there is an enormous amount of data that could be reviewed and analyzed to look for trends in how students work and learn or to look at the effectiveness of various types of questions for different types of students.

Conclusions

Our system has evolved over the last three years from a proof-of-concept trial implementation into a critical component of our engineering fundamentals courses. It has been well received by both students and faculty, and it has received very favorable feedback from students who have used other online homework systems for other technical classes. The integration with the discussion board and the database has been a key aspect of the success. It continues to be developed by faculty directly involved in its daily use based upon feedback from faculty and students. It has proven to be a significant improvement over a complete paper-based homework system and an invaluable teaching and learning tool.

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