Session 2649

# Use of Web-Based Testing Software for Problem-Based Learning in Hydraulics and Hydrology

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## Abstract

LON-CAPA is web-based course management software supported by Michigan State University. It includes a testing component that allows for coding a variety of sophisticated problems that are computer-graded and submitted by students on-line. Each student can be given problems having unique parameter values. Grading can be done on a "mastery" basis with the student given multiple attempts to solve the problems.

LON-CAPA was used for problem-based learning activities in EGTE 321, Storm-Water Management, at the University of Delaware. Problems were formulated to emphasize analysis and design of storm-water management systems. Problems included components involving open-channels, vegetated waterways, water-surface profiles, culverts, storm-drains, NRCS TR-55 hydrology, and reservoir routing – conceptually difficult subjects for many students to master. Advantages of using LON-CAPA with problem-based-learning methods included:

- Mastery-based learning encourages students to work on problems until they get them right. With standard grading systems, students do not get immediate feedback and do not have the opportunity to be as persistent in finding the correct solutions.
- Once problems are coded, demand on instructor time decreases because problems are computer-graded. Mastery-based learning becomes much more feasible.
- Students have unique numbers for their problems. Cheating is difficult. Students can be encouraged to discuss with one another the concepts required to solve the problems but cannot simply give one another the answers.
- LON-CAPA gives the instructor the ability to check values of intermediate calculations required to arrive at the solutions of each student’s problems. This feature makes it possible quickly to identify the points with which the student is experiencing difficulty. Misconceptions and gaps in knowledge can be readily addressed.

This paper includes strategies for writing problems that are suited for development of design and analysis skills in engineering-related topics and provides examples. Techniques for coding solutions to complicated problems with a minimum of “bugs” are also discussed. Student comments and preferences regarding use of the LON-CAPA system in conjunction with Problem-Based Learning are examined.

## Introduction and Background

LON-CAPA[1] (Learning ONline – Computer Assisted Personalized Approach) is web-based nonproprietary course management software that has features comparable to those of the well known proprietary software packages WebCT[2] or Blackboard[3], but with additional capabilities in the form of sophisticated testing and assessment components. LON-CAPA integrates testing and assessment features from CAPA[4], an earlier non-web network-based software application, designed to provide individualized homework assignments, quizzes, and examinations for each student. Distribution of the open-source LON-CAPA software is free through Michigan State University under a GNU license[1].

The objective of the research reported in this paper was to use the LON-CAPA homework system to support a problem-based learning approach for teaching hydrology and hydraulics topics in the University of Delaware course, EGTE 321, Storm-Water Management. This paper will discuss issues regarding implementation of the LON-CAPA system and assess the impact on students and student acceptance of the pedagogy by relating instructor classroom observations and examining results of a student survey.

LON-CAPA is designed to run on the LINUX operating system. The current release is designed for simplest installation using the Red Hat 7.3 version of LINUX. Coding of problems is accomplished using Perl, a powerful open-source interpreted language native to LINUX and UNIX operating systems. LON-CAPA is flexible; it can be used to create problems or questions that emphasize either quantitative solutions or conceptual understanding. Coding of a variety of problems is possible and can include numerical, symbolic, logical, graphical, matching, multiple choice, and essay features. Problem statements can incorporate links to other resources even including animations that illustrate motion and other changes over time. Components of the problems such as values for parameters and the set of parameters itself can be randomly assigned by the computer. Students are given immediate instructor-programmed but computer-generated feedback to their responses.

An example problem statement and input screen are shown in Figure 1 as they would appear to a student upon first opening the problem. In this problem, the cross-section dimensions, the channel slope, the roughness coefficient, and the flow rate are all randomly generated so that each student has a unique set of parameter values. The labels on the figure automatically display the correct values for the dimension variables.

The testing and assessment components of LON-CAPA can be a particularly valuable tool for the instructor teaching large classes in mathematics, science, and engineering. Potential benefits are not limited to the hard sciences and engineering, however. In particular, the individualized homework problems can prove to be an important addition to any class in which student learning is highly correlated with the time spent "on task" in the application of learned problem solving skills or in self-directed examination and discovery related to the course subject matter.

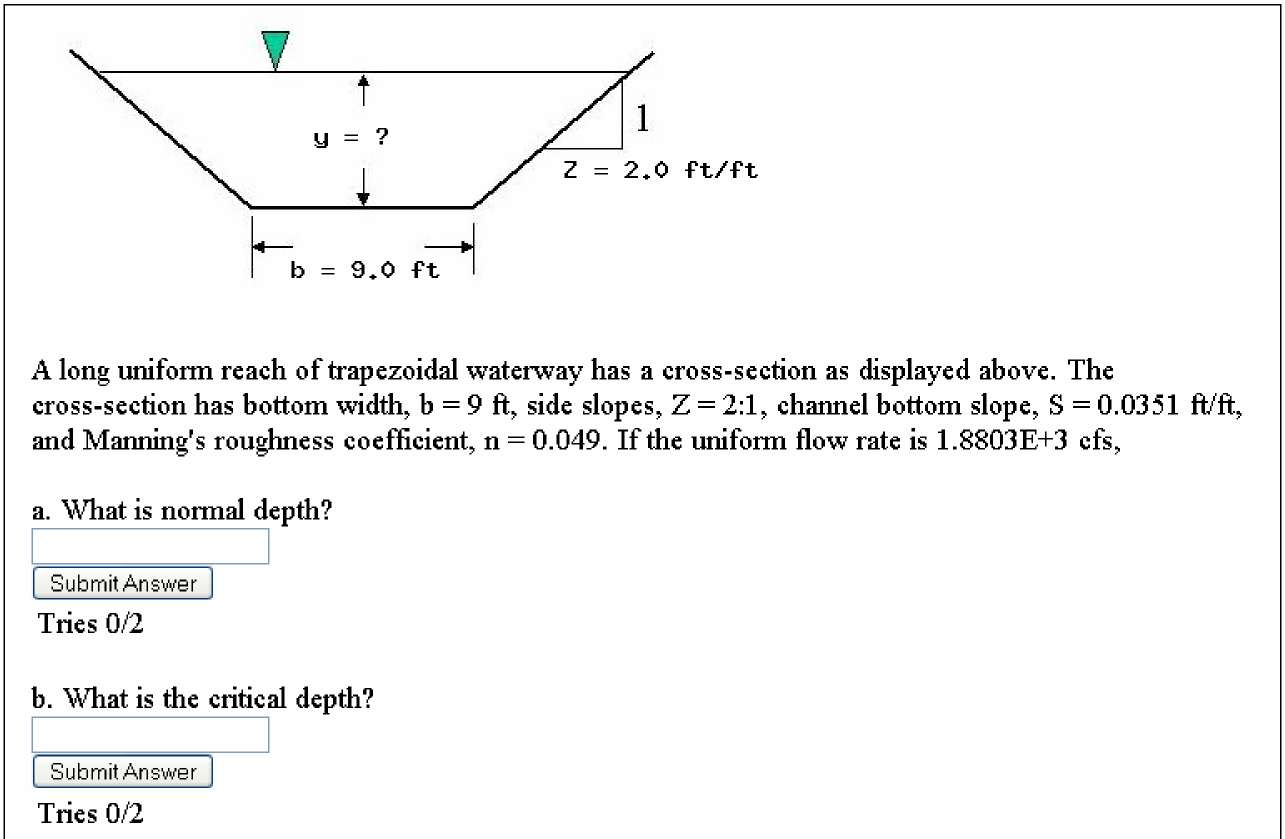


Figure 1. Sample problem statement and input screen seen by student.

Kashy et al.[4] reported the results of a study in which CAPA was used to provide individualized homework problems, quizzes, and examinations for students in several introductory level physics courses. The study spanned eight years and compared results over time, between conventional and CAPA-enhanced courses, and between sexes. Some key results of the study were[4]:

- Students increased the time they spent working on assignments and other course requirements by a factor of over 2. (It approached a recommended 2-hours outside of class per week for each lecture hour.)
- Typically 80% of students believed CAPA helped them learn and understand the course material.
- Frequent assignments with firm electronic deadlines encouraged the students to keep up with the pace of the course. The tendency of some students to procrastinate and fall behind was discouraged.
- The initial development, specifically for CAPA, of well-tested course materials that are designed to improve conceptual understanding is a costly process for the instructor in terms of both time and effort.

**Identification of Problem and Implementation of LON-CAPA Enhanced PBL**

EGTE 321 is a four-credit lecture/lab course that meets weekly for two one-and-a-half-hour lectures and one two-hour laboratory per week. EGTE 321 is a required course for the Construction Technology and Technical Management concentration in the department's Engineering Technology major. Topics include hydrology for small urban, suburban, and rural watersheds, and design of culverts, storm drains, spillways, vegetated waterways, and storm-water management systems. A hydraulics course is a prerequisite. Because of the highly computational nature of the material, the course is taught in computer laboratory with access to the web and spreadsheet, hydraulics, and hydrology software.

Proper design of storm-water management systems depends on a solid understanding of surface-water hydrology and open-channel hydraulics. Neither of these subjects nor any technical subject in general is grasped easily by a student without the student investing significant "time-on-task" actively manipulating and being engaged with the concepts, calculations and procedures involved.

In previous years, four to six homework problems in EGTE 321 were assigned weekly and students were put on notice that some homework problems would appear on upcoming tests. To provide immediate feedback, students were given the problem answers but were required to show detailed solutions so the instructor could gage student understanding. As part of each exam, students were required to hand in several pre-worked homework problems for the topics covered on the exam that would amount to approximately 30% of the exam grade. Repeatedly, unwanted outcomes from this policy were observed that instigated a search for a more effective way to have students work actively with the course material:

- Students would put off doing the homework problems until immediately before the exams and, hence, did not get the benefit of working with the material in a timely manner right before the related ideas and principles were to be applied as a springboard to more advanced concepts.
- Students would get hung up on small misunderstandings or misperceptions while working on problems by themselves and simply give up. Many would not bother to seek help from the instructor even with constant encouragement to do so.
- Students would collaborate on solving the problems, which in itself is not bad; but typical student behavior would short-circuit the intended learning process. When collaboration degenerates into simply giving one another the solution, the person who receives the information derives no benefit; and both people are violating standards of academic honesty.
- Since students knew the answers to the assigned homework problems, they became adept at "reverse engineering" the solutions. While reverse engineering requires some ingenuity, it bypasses the learning the student is intended to derive from working the problems the "right way."
- A surprising number of students were willing to "take their chances" by doing only some of the assigned problems or just the easier ones. They were willing to gamble that either the problems they skipped would not be on the exam; or if the skipped problems did appear on the exam, they would be able to muddle their way through during exam administration.

- Because the less motivated students had not actively worked with the technical material for a sufficient amount of time, they were unprepared to work new exam problems similar to the homework, but which they had never before seen.

It seemed the only way to assure that students who were at least modestly motivated were spending the required amount of time at problem solving was to collect and grade all homework problems – and to count the homework problems as an important component of the final grade. Even for a relatively small 15-30 student class, which is a typical for EGTE 321 and two other courses taught by the instructor, such a commitment requires a significant amount of time. Use of a PBL-type approach in conjunction with the LON-CAPA homework system in EGTE 321, not only helps to ensure that students get a substantial time-on-task component but also addresses either directly or indirectly the other problems described in the list above.

In what is conventionally envisioned as problem-based-learning (PBL), students work in small groups to understand and integrate key information by identifying, researching, and applying concepts and practices needed to solve complex realistic problems[5]. The goals in the application of PBL discussed here are somewhat more modest. The primary goal is to increase time students spend "on-task", actively working with concepts by engaging in problem solving. In summary, the anticipated benefits of computer-assisted PBL through LON-CAPA included:

- Firm electronic deadlines for problem assignments would encourage students to stay on track by actively mastering key concepts required for progression through the course. Students master the material by spending significant time in active learning.
- High-value time with the instructor would be spent in active learning and problem solving. Inefficient solitary student "head scratching" would be greatly reduced. There would be increased interaction between students and instructors. For the PBL component of the course, the instructor would act more as a "coach" as opposed to evaluator. Interaction with students should improve.
- Collaboration would be encouraged because students can't give each other the answers. Students are forced to discuss concepts and procedures for solving the problems, instead.
- Students would get immediate feedback on their responses but wouldn't know the answers to the problems, thus eliminating the ability to "reverse engineer" solutions when the answers are known, as is the case with textbook problems that show answers. Multiple attempts encourage the student to work on a problem until it is successfully solved.
- Since the computer does the grading, after problems are coded, demand on the instructor's out-of-class time would decrease.

Previous offerings of EGTE 321 used WebCT for posting of course materials and assignments and for group discussion features. Though it was possible to use LON-CAPA for these purposes, to ease transition effort, the instructor continued to use WebCT for its posting and discussion features and used LON-CAPA for its homework system features only. The first two-thirds of the course were devoted to development of analysis and design skills in hydraulics and hydrology that would be needed for a team project requiring the detailed design of storm-water management system for a proposed residential site. The remaining one-third of the course was reserved for teams to work on the design project.

Students were required to prepare for all class meetings by reading the posted assignments in detail. At the beginning of each class meeting, ten to fifteen minutes were reserved for a brief overview of the material by the instructor and for the students to ask questions about the reading assignments and other materials. For days not devoted entirely to team activities, the remainder of class time was used for individuals to work on solution of posted LON-CAPA problems.

A mastery-based learning approach was employed for the LON-CAPA problems. Problems were intended to reinforce the topic of the day or week by requiring use of the fundamental hydraulics and hydrology concepts and the analysis and design procedures that students were exposed to initially through the assigned readings. Students were allowed multiple attempts at solving the problems. Students received full credit for all homework problems completed regardless of the number of attempts as long as they were completed by the electronic due date (typically about one week after problems were posted). The instructor set an upper limit of 20 attempts on any one problem to prevent students from simply hunting for the correct answers. The instructor would increase any individual's allowable attempts after discussing with the student his or her strategy for solving the problem. Many if not most students were capable of completing the problems during the allocated classroom time alone. Problems not completed by the due date received zero credit. Homework accounted for 20 percent of a student's overall grade in the course.

Some might question the wisdom of allowing unlimited attempts and giving full credit for problems completed by the due date regardless of the number of attempts. In this application, the primary objective was to get students to spend additional "time-on-task" engaged in problem-solving activities. Kashy et al.[4] found that "Allowing multiple tries on assigned problems with no penalty is highly motivating; most students strive to get all the work done correctly." Since problems were written in such a way that guessing was unlikely to result in a correct answer, the instructor was satisfied with merely getting students to spend more time on the work and not concerned so much with using the problems as a grading tool. Problems could also be made somewhat higher in difficulty because multiple attempts were allowed. Less-motivated students did not finish all problems, so some grade differentiation did result.

Several LON-CAPA features were particularly valuable to the instructor for helping students understand how to solve the problems. Since all students have different numbers for their problems, the instructor does not immediately know the correct answer for each student's problem. The LON-CAPA *Chart* function allows the instructor to see the correct solutions to any student's problems, but equally important, it contains a feature that allows the instructor to view values for the intermediate calculations required to solve the problems. This feature allows the instructor to compare the student's intermediate calculations to those done by the computer. Using the *Chart* feature, it usually is possible quickly to identify the point at which the student's solution breaks down and to ascertain what help or advice is appropriate at that time. It is also possible to see a history of the student's attempts at solving the problems. This gives the instructor additional insight into the student's strategy for solving a problem that may not be conveyed through initial conversations with the student.

## LON-CAPA Problem Design and Programming Considerations

To facilitate use of the LON-CAPA homework system with a mastery-based PBL approach some guidelines were followed in developing problems. Because students are given multiple attempts at solving the problems, numerical problems are better suited in comparison to multiple choice, simple matching problems, or most obviously, True/False. Problems can be designed with multiple parts that can be submitted independently as in Figure 1 or multiple parts that are submitted all at once as in Figure 2.

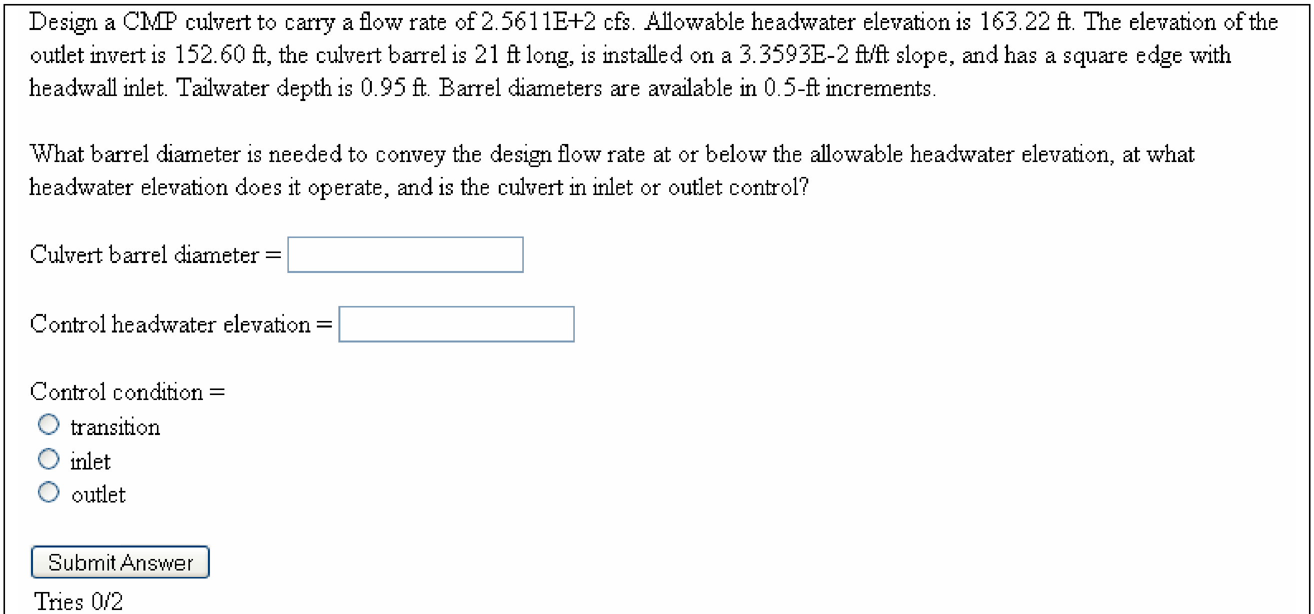


Figure 2. Multiple answers as a single submission for a culvert-design problem.

For complicated problems with many intermediate steps involved, it is helpful to have the student progress through the solution one part at a time. If the problem parts follow the general sequence of solution the student will use, the parts can be submitted independently and will serve to step the student through the solution in such a manner as to alert him or her when a mistake has been made in an intermediate calculation. This can help the student "self-diagnose" difficulties when they arise and to narrow down concepts or procedures to which that particular student needs to give more attention.

Figure 3 displays a LON-CAPA problem statement and submission screen after answers have been submitted. A correct answer for part *a* was submitted. LON-CAPA responds with a "You are correct message" and a printout of the correct answer with the proper units shown. The student can record the receipt number as verification that he or she correctly completed the problem. A simple hint is displayed below the answer box for part *a*. The LON-CAPA *hint* feature allows the instructor to provide additional information that can assist the student in understanding the problem. It can be conditionally tied to different student responses; but in the default mode, it is simply displayed after the *submit answer* button is used.

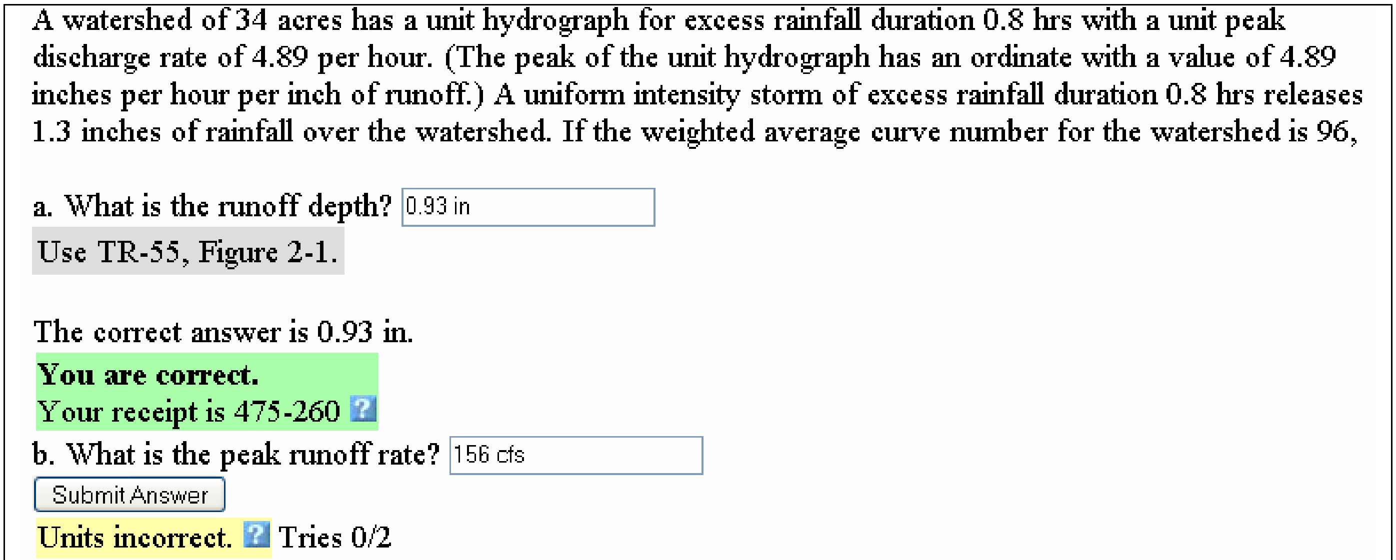


Figure 3. LON-CAPA responses to submitted answers.

When problems include different unit systems or even conversion between units in the same system, it is good to require that students supply units with the answers so they are explicitly made aware of the relationship between units and reminded to verify that they have done conversions correctly. In part b of the problem displayed in Figure 3, an incorrect form for the cubic feet per second units was used. LON-CAPA would have recognized units expressed as “ft^3/s”. No penalty is assessed for responses that are in an incorrect form. Notice that the tries counter still registers zero of a maximum of 2 tries for this problem. (The instructor can set maximum tries as high as 100.) For an incorrect answer, LON-CAPA responds with an “incorrect” message followed by the counter displaying the number of tries used and the maximum allowed.

It is advantageous to write some problems in the forms shown in Figures 2 and 3 rather than as in Figure 1 so that multiple answers are submitted all at once with a single push of the *submit answer* button because a computer response of “incorrect” does not reveal which submitted answers are wrong. The culvert design problem shown in Figure 2 is a good example. Culvert barrels are available in relatively few standard inner diameters. If one part of a culvert design problem only required finding the right barrel size for given conditions, it would be a simple matter for the student to use the multiple attempts to just guess barrel sizes until he or she found the correct diameter. When a desired answer has a limited number of possibilities, a good strategy is to require the student to simultaneously submit additional information.

Figure 2 shows the problem statement and answer screen for a LON-CAPA culvert design problem that uses a single submission for multiple answers. The methodology described in the FHWA publication, HDS-5[6] is used for the solution. In this problem, the student must submit answers for culvert diameter, headwater elevation, and control condition. The headwater elevation and control condition must be correctly determined in intermediate steps to obtain the proper culvert diameter. Their inclusion as part of a single submission of multiple answers virtually eliminates the possibility of the student correctly guessing the culvert diameter, as might happen if the culvert diameter were one of multiple individual answer submissions for which multiple attempts were allowed. One part of the problem in Figure 2 includes a radio-button response feature. LON-CAPA allows a rich variety of response options in addition to the numerical and radio button responses illustrated in Figures 1, 2, and 3. Other answer formats include: option response, string response, and formula response.[7]

Regardless of the answer format or the specific calculations needed to code the computer solution in Perl, the instructor should program in parameters to represent all the intermediate calculations needed to solve the problem. As noted earlier, LON-CAPA lets the instructor look at the values of all variables defined in the problem's Perl code for any student's unique set of parameters, which is very helpful in discovering student errors or misconceptions. It is also tremendously useful for the instructor to be able to see the values for these intermediate calculations when debugging the problems he or she has written.

Considerable care needs to be taken in defining appropriate error tolerances for the numerical response answers. Some calculations are very sensitive to round off error. Every attempt should be made to make sure that numbers given to the student in the problem statement contain little or no round off error. As much as possible, the Perl code should follow the same steps for solving the problem that a student would use, and the student should see *exactly* the same numbers that the computer uses for its calculations. Some problems are more sensitive to round off error and require special attention to these details. Such a programming strategy will minimize the chance of discrepancy between answers obtained by different solution methods.

Occasionally, it may make sense to program a problem in a way very different from how a student would approach its solution. Sometimes the impetus may be simpler more reliable Perl code. Consider, for example, the problem displayed in Figure 1 for calculation of normal and critical depths in a trapezoidal channel. In the problem statement to the student, flow rate, roughness coefficient, channel slope, and channel dimensions are values given. With this information in a trapezoidal channel, normal and critical depths must be obtained by iteration.

Rather than solve for normal depth, it is computationally more efficient first to assign randomly a normal depth and calculate a flow rate from Manning's equation. Once a flow rate is calculated, the only iteration required is for critical depth. Pseudo-code for the problem could be summarized as follows:

1. Randomize the channel parameters, including the normal depth of flow.
2. Calculate cross-sectional area, a, and hydraulic radius, hr, at normal depth.
3. Use Manning's equation to calculate the flow rate at normal depth.
4. Use the bisection subroutine, bisect, to find critical depth by defining a function to be zeroed, phi = $N_f - 1$, where $N_f$ is the Froude number.

Channel parameters, cross-sectional area, hydraulic depth, and hydraulic radius, are defined explicitly as variables in the intermediate calculations for the purposes of debugging and checking against student work. Froude number is also calculated as a check at critical depth. Flow rate and channel bottom slope are displayed in the problem statement to more significant figures than would normally be warranted so that round off errors can be reduced when the student calculates normal and critical depths by iteration.

An alternative method of programming the problem in Figure 1 that could result in even simpler Perl code would be to follow the summarized pseudo code shown below:

1. Randomize channel dimensions and parameters
2. Pick a critical depth, $y_c$, to a hundredth of a foot that yields a flow rate as calculated from the relation $Q = A(gD)^{½}$ where Q is flow rate (cfs), A is cross-sectional area ($ft^2$), g is acceleration of gravity (32.2 $ft/sec^2$) and D is hydraulic depth (ft).
3. Randomly choose with specified probabilities a normal depth, $y_n$, to a hundredth of a foot that is either subcritical ($y_n > y_c$), critical ($y_n = y_c$), or supercritical ($y_n < y_c$).
4. Use Manning's equation to calculate the slope corresponding to $y_n$.

This approach would eliminate the need for iterating to find either normal or critical depth, but some additional complexity would result if one wanted to ensure that values of flow rate and slope were in reasonable ranges. This method has the advantage of giving the programmer control over the frequency with which different regimes of flow are picked. It would still be important to print slope and flow rate to high accuracy to avoid round off errors in student calculations.

It is particularly frustrating for the student to be doing a problem correctly but to be flagged by the computer for a wrong answer when normally insignificant round off error is introduced. The student may end up spending unnecessary time trying to solve a problem for which he or she has already obtained an essentially correct answer. For this problem, illustrated in Figure 1, it is also a good idea to use a larger tolerance for the normal and critical depth answers than would be normally associated with depth values that were specified to one hundredth of a foot. Rather than a tolerance of ±0.005 ft, a tolerance of ±0.01 or ±0.02 would help to reduce student answers identified as wrong when in fact the student had done the calculations essentially correctly but had introduced some fundamentally insignificant round off error. It is also possible to specify tolerances in terms of percent, a particularly useful feature when the magnitude of the answer can vary over a wide range.

To ease programming effort and reduce coding errors, one should make use of the subprogram and library features of Perl as much as possible. Library files can be published and linked to problem files in LON-CAPA in a straightforward manner. As an example, a library file of hydraulic cross-section functions, hyd_xsection.library, was created for EGTE 321. This library file contained subprograms for cross-section parameters such as cross-sectional area, hydraulic radius, and hydraulic depth. These functions were written with logic blocks that allow the typical selection of cross-section types used in storm-water management: circular, trapezoidal, parabolic, and unit width. A library file of iteration subroutines, iteration.library, was also created. Having these library files containing debugged and reliable cross-section and iteration functions greatly simplified subsequent programming and undoubtedly reduced programming errors. The libraries are linked through a simple "import file statement" in the XML code.

**Results and Discussion**

To get the students' impressions of the PBL method as used in EGTE 321 and to help gage the student-centered benefits of the LON-CAPA system, the instructor asked students to complete an anonymous survey by posting responses to an anonymous discussion folder in WebCT. The survey posed the following questions or requests for comment:

1. What is your opinion of the problem-based learning (PBL) approach used in this class whereby less class time is spent in lecture and more is devoted to problem solution by individuals or group work on projects while the instructor is present to provide guidance and answer questions? Do you have any suggestions for improvements?
2. What are some specific advantages/disadvantages of using the computer-based LON-CAPA problems in the PBL context? In particular,
   a. How does the experience in this class compare to solving homework problems from a textbook?
   b. Do the LON-CAPA problem sets enhance the PBL approach or detract from it? How?
3. With the PBL approach, little class time has been used for a traditional lecture presentation during which the topics covered in the course are explained in detail. Instead, students are expected to prepare for class by doing the reading assignments beforehand. Have the reading assignments in this course been adequate? Have you usually been prepared for the class activities? If not, what would motivate you to come to class better prepared (e.g. a brief content quiz at the beginning of each class)?

Responses were received from 12 of 16 students. Overall, opinions were split between a majority who seemed to favor the PBL approach with LON-CAPA and somewhat fewer who did not. This was the instructor's first attempt at using the LON-CAPA system for problems of the complexity encountered with the hydraulics and hydrology topics that are the subject of EGTE 321. Some snags were anticipated with software and programming bugs, and problems were encountered. Some difficulties were due to the aforementioned tolerance considerations for numerical answers, others were results of instructor errors in programming the Perl code, and still others resulted from bugs in the LON-CAPA software. Students were particularly critical of all such problems.

It should be noted, however, that when students had difficulty answering LON-CAPA questions, usually they were simply doing the problems incorrectly. Most times, when students made the statement "The computer's wrong.", further investigation identified an erroneous assumption or calculation – not programming bugs or merely excessive round off error.

Judging from the responses to question 1, a number of students appeared to be unfamiliar and/or uncomfortable with the PBL method. Five of the twelve students were either critical of the limited time devoted to lecture or expressed a desire for more lecture time. As noted by Felder[8], students who are unfamiliar with PBL may, on first exposure, exhibit outright hostility to the methods employed – particularly those that rely on student initiative for self-directed learning. Students rarely took advantage of the opportunity to ask questions related to the day's topics during the time provided at the beginning of lecture, but some were still critical of a perceived lack of opportunity to obtain further explanation:

*I would like more lecture ...when a problem is solved in class there is an opportunity to question procedures that are not clear.*

Another student exhibited hostility to the PBL approach in writing this in response to question 3:

*…If PBL seems to be so valuable to this course, why is this the first course I have taken in my 4 years at this university that is based on problem based learning. A course with 2 or 3 hours of lecture is supposed to contain exactly that, lecture. ...*

Felder[8] does offer some strategies for raising student comfort level that may be of value in future offerings of EGTE 321 and other course in which LON-CAPA and PBL are used. The positive responses to question 1 do, however, reinforce a standard motivation for use of PBL: active learning is superior to passive learning. Some typical positive responses to question 1 were:

- *I like the PBL approach, especially since I can figure out most of the information on my own and not be bored with a traditional lecture. Plus, I like being able to complete my homework in class rather than outside on my own time.*
- *The PBL approach is very helpful in learning to calculate and solve for given problems. It is easier to learn by working out problems than just listening to a lecture. However, it requires more time outside of class than other courses of the same level.*
- *I like it. Stuff only sinks in with me if I build from the bottom up and understand every step along the way. Having the teacher there to answer my questions while I'm working problems is nice.*

One student complained that the instructor was not always immediately available to answer questions during the class period because the instructor was helping other individuals at that moment. Surely, however, the immediate feedback provided by LON-CAPA and a brief delay in getting assistance from the instructor is preferable to the situation that students encounter with hand-graded work done out of class: feedback in one or two days at the earliest and **no** immediate access to instructor assistance.

From student responses to question 2a, it appears that the immediate feedback feature of LON-CAPA and the mastery-based learning approach appealed to many students. Seven of the twelve student responses to question 2a were generally positive, three were neutral, and two were negative. The following response, though negative, reinforces one of the instructor's motivations for using the LON-CAPA system. This writer disregards the immediate feedback

feature and the availability of the instructor for answering questions and complains that everyone's answers are different:
*We can at least help each other out if the problems were from the textbook, whereas the lon capa had all different numbers so we wouldn't even know if we were doing it right when we asked each other because our problems were different.*

It's possible that the help to which this writer refers might not extend any further than the value of the correct answer. The positive responses to question 2a indicated that the immediate feedback feature was particularly important, as is evident in these examples:

- *I like the online approach better because particularly in this course, I would have probably done worse with problems from a textbook.*
- *I like having multiple tries and immediate feedback with the LON-CAPA system. If I had to do the problems from a textbook I think I would not have gotten as many right and would not have learned how to solve the problems correctly.*
- *I'd rather do lon-capa where it has the different steps in solving a problem. That was a very effective way for me to learn, rather than out of a textbook where you usually don't even know if you're doing it right.*

Student responses to question 2b indicated that the majority (8 positive, 1 negative, 3 neutral or mixed) thought LON-CAPA enhanced the PBL method used in EGTE 321, but three students pointed out problems with software bugs. Several students mentioned increased interaction with the instructor or their peers as a specific benefit. Two examples of the positive responses to question 2b were:

- *They help the PBL approach, because you can ask questions as you go and there is a lot of student interaction, which builds teamwork skills, because every problem has different given variables for each individual student.*
- *Enhances it, because it makes it easier for the instructor to help the students when they are having problems. The instructor can check the problem step by step and see where the student is making a mistake*

Student answers to question 3 mostly indicated that the reading assignments and class notes posted on the WebCT site were adequate preparation for class work. The several students who had a negative opinion of the PBL method employed in EGTE 321 did not really answer the question but instead voiced complaints about the pedagogy. Of the five people who voiced an opinion regarding a content quiz at the beginning of each class period, three felt it would motivate people to come to class better prepared; and two did not.

Several students indicated they came to class prepared, but from instructor observations, it was obvious that many people were unfamiliar with the topics and the assigned readings at the beginning of most classes. Students wasted considerable time scanning the class notes for material related to the LON-CAPA problems. It was difficult to elicit questions from the students at the beginning of class, even though many did not thoroughly understand the material. One suspects that many students behaved as did this respondent, who waited until he or she encountered problems with the LON-CAPA assignments before asking questions:

*For this class, I usually skim the reading assignments and wait to see if I have any problems answering Lon-Capa homework before I ask questions. The readings do help with understanding the assignment, especially the power-point notes, which are essential to this course. I don't think a quiz in the beginning is worthwhile, considering the material is easy to figure out on your own and most people come to class prepared to do homework and projects.*

It is much better use of time to have questions voiced before the entire group so that they can be addressed once for everyone who might be similarly confused. A brief content quiz at the beginning of class, perhaps administered through the testing components of WebCt or LON-CAPA, may be an appropriate motivator for students to come prepared. An opportunity for students to ask questions before the quiz would encourage points of confusion to be addressed before the whole class. Some responses concerning preparation were:

- *The reading assignments are good in that they have a good explanation of the topic and usually good examples of how to apply the concepts, but they tend to be long. I usually prepared for class. My motivation for reading was so I could focus on working problems during class instead of wasting time reading.*
- *I often did not come to class prepared but found the Lon-Capa problems approachable even when not prepared for class. A quiz in the beginning of each class period would have motivated me to come to class prepared.*
- *The reading assignments where adequate to the course, sometimes they even covered more than you needed to solve the LON-CAPA HW problems. I usually would be prepared for classes by reading the assignments. However, I did because I thought it would help me understand the HW problems better, so I wouldn't waste time going through the power point notes* [during class]. *I don't think a quiz would be the best way to motivate the student, but it would certainly increase the number of students that would prepare for class.*

With the exception of several students who had a strong negative reaction to the PBL method, the approach used for teaching EGTE 321 was generally well received. Overall, the responses reinforce much of the initial rationale for adopting the LON-CAPA system coupled with PBL and agree with results obtained by Kashy et al.[4]. In particular, the learn-by-doing method was very important for helping some students master the material.

The instructor experienced increased student-instructor interaction and observed increased interaction among students themselves. Using this approach to PBL, the instructor spent the bulk of classroom time working with students as individuals or in small groups providing additional details about the topics and discussing strategies for solution of the LON-CAPA problems. Once the storm-water design project was begun later in the course, the majority of class time was devoted to discussions with groups and sometimes the whole class about design of individual components and about design strategies for the overall system.

The instructor frequently noted that the increased student interaction and collaboration in solving problems was positive in nature. Students could be seen drawing diagrams for one another, pointing out components of equations that had been omitted or written incorrectly, and generally helping one another understand the material. This student-to-student interaction in the first part of the course was undoubtedly beneficial when group work on the design project commenced later in the semester.

Instructor observations also confirmed that the immediate feedback from LON-CAPA and the mastery-based learning made possible by multiple attempts were important features for the students even though many did not mention those features in the student survey. Students also appreciated the hint feature. The PBL approach required students to spend significant time-on-task solving the LON-CAPA problems. Immediate feedback and multiple attempts motivated them to put more effort into the LON-CAPA problem sets than they might otherwise have devoted to conventional hand-graded homework problems.

**Summary and Conclusion**

The implementation of a computer-assisted PBL pedagogy in the University of Delaware Engineering Technology Course, EGTE 321 Storm-Water Management, was discussed and examples were provided that demonstrated different approaches to structuring LON-CAPA problem statements and solutions for topics in hydraulics and hydrology.

Based on the results from the first semester of using the LON-CAPA homework component in conjunction with PBL in EGTE 321, there is sufficient justification to continue efforts in EGTE 321 and to expand its use in other courses. Results of the student survey and instructor observations point out a number of positive outcomes from using LON-CAPA in conjunction with a PBL in EGTE 321. Among the most important are:

- Electronic deadlines helped keep students from falling behind.
- Students spent increased amount of "time-on-task" in an active learning mode.
- Interaction between students and with the instructor increased.
- Student collaboration was redirected from activities detrimental to learning to activities that reinforced learning.
- Immediate feedback and mastery-based learning were important features of the LON-CAPA system that motivated students to devote more effort to problem solving. Since students were unaware of the correct answers until the problems were solved, the possibility that the students could "reverse engineer" problem solutions was eliminated.
- Though the initial time invested in authoring LON-CAPA problem sets was significant, in subsequent offerings of the course, overall demand on the instructor's time will be lowered by a reduced amount of time spent on grading.

Offsetting these benefits were the occasional problems with student submissions for which LON-CAPA yielded false negative responses. Students were understandably disturbed by these instances, which no doubt clouded the overall experience for some people. Further refinement of the programmed problem solutions, problem formulation, and the LON-CAPA system itself should correct most such troubles in the future. Because of the impact on student acceptance, avoiding bugs in the programmed problem solutions and false negatives for correct submissions must be a prominent quality control concern.

Because most students are unfamiliar with the PBL method, it might be worthwhile to spend time at the beginning of the semester transitioning to PBL and getting the students oriented so that they are more comfortable with PBL and can take full advantage of the format.

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