Personalized Thermodynamics Homework Problems—Pilot Study

ASEE 2005-734 Roy W. Henk, LeTourneau University

Introduction

Personalized homework problems are enhancing the instruction of engineering thermodynamics by providing immediate feedback to students and faculty. In the engineering school at LeTourneau University, we piloted a set of thermodynamics problems that were personalized for each student in the class. These problems followed the protocol for a computer-assisted personalized-approach (CAPA) to learning on-line (LON) that was developed at Michigan State University (MSU). The LON-CAPA system has been successful for instruction of the natural sciences [1, 2, 3, 5, 6, 8]. At LeTourneau, we have extended the CAPA tools to the instruction of engineering thermodynamics.

Mastery of thermodynamics concepts requires students to solve problems using several steps to achieve the desired learning results. Practice using multiple steps to discover the final answers is essential. When required to provide an answer at each logical step, each student strengthens his or her problem-solving technique in addition to arriving at the correct final solution. Computerized assessment of each individualized homework problem gives immediate feedback to the student. Individualized problems encourage collaboration about the process of solving the problem without allowing students to uncritically copy another's answers.

Description of the CAPA system

The CAPA system hosted the individualizing of problems, provided feedback to the students and faculty, and reduced the load on faculty and graders. Individualized problems meant that the correct answer was unique for each student. This required that each student solve his/her own homework and that each homework problem be graded individually.

CAPA homework was administered to students online. Each student received a distinct pass code to access his/her individualized problems. Some students printed out the problem to work offline, to keep a record of their results, to bring to class for discussion, and to use in studying for tests. Appropriate student collaboration on concepts and solution methods was encouraged. When the student supplied answers, immediate feedback was provided indicating whether the student's answer was correct. The system benefited students with special learning or physical needs. LON-CAPA provided feedback to instructors as well, enabling them to spot troublesome concepts and to identify students who needed special assistance. After the due date, the homework set was closed but still accessible, and students then moved on to the next topic.

Goals

The goals of the pilot study were to:

- adapt the CAPA system to the instruction of engineering thermodynamics by creating problems according to the CAPA protocol, and
- enhance thermodynamics instruction by increasing student accountability.

In an average thermodynamics course at LeTourneau University, about 150 problems are assigned for the students to attempt. Optimally, homework will be composed of a combination of CAPA problems, providing immediate feedback, and a reduced number of traditional problems which receive thorough hand checking.

The eventual goal is to develop 100 engineering thermodynamics problems following the LON-CAPA protocol. The CAPA thermodynamics problems created will exercise the core concepts in popular textbooks and will be indexed to similar problems in these texts. We will test the problems to ensure they are debugged and assessed for "discrimination" and "degree of difficulty." Then the problems will be disseminated nationwide to engineering schools via MSU.

CAPA-type Problems

The instructor created two types of LON-CAPA problems: traditional and conceptual. A traditional thermodynamics problem converted into a CAPA-based problem with multiple steps is shown in Figure 1. By careful placement of questions at logical intermediate steps, this problem guided students toward understanding the concepts and achieving the desired results using better problem-solving techniques.

Traditional problems in CAPA were effective in inhibiting students from copying another student's work and other forms of cheating. Students were free to collaborate on the process of solving problems without the temptation to copy another student's final answers. When during collaboration a "magic" formula gave the correct answer for one student's homework, but didn't give the correct answer for another's they then discovered that the "magic" was wrong and wisely reworked the problem to correctly solve it. This reinforced one goal of training engineers since in the workplace, colleagues often collaborate and must verify their answers.

Conceptual LON-CAPA problems, such as the one shown in Figure 2, are more challenging to create and can be more effective than their traditional counterparts at testing students' understanding [4]. Conceptual problems go beyond traditional textbook exercises. CAPA problems can present multiple concepts in one problem reducing the number of questions students must complete, minimizing complaints about too many homework problems. One example created by the instructor incorporated four textbook problems into one CAPA problem.

Class Enhancement

A visiting educator remarked that students assigned CAPA problems were notably more engaged with the concepts taught and with the subsequent homework. The instructor experienced an increase in questions from students during classes that encouraged discussions on the current material. In-class dialogue revealed areas in which students did not clearly understand certain processes required to solve different problems. It was then easy to note which parts of formulas were misapplied or unclear to students. The discussions were productive, and less-astute students benefited from the questions of others. CAPA problems also encouraged students to complete homework. Student feedback on recent evaluation forms included the following: "CAPA is a great tool! It helped me big time to learn and practice."

Results of the Pilot Study

1. To date, more than 40 CAPA problems in preliminary form have been piloted with students.
2. An increase in student accountability was apparent. Students were more diligent in completing assigned CAPA homework. Students across the grade spectrum completed CAPA homework more successfully than traditional homework problems turned in for grading. Figure 3 shows that on average, students successfully completed about 8% more of their CAPA homework than traditional homework. Students in the top third of the class submitted most of their homework, including CAPA homework, and ensured their success by the immediate feedback from CAPA. Some students at the middle and lower end of the grading spectrum completed more than 20% more CAPA homework than traditional homework.
3. A student usually was allowed a specified number of attempts for each answer. For example, this professor selected 5 tries. When students did not answer correctly, the computer provided hints in the form of a suggestion to lead the student to the correct solution. Whenever students made four unsuccessful attempts and continued to have difficulty, they adamantly asked questions in class or sought out the instructor for greater explanations and guidance.
4. CAPA reduced the time gap between "doing" and "grading" from days or weeks to instant feedback, simultaneously increasing the quality of feedback. By requiring an answer at each

logical step, students strengthened their problem-solving technique as they arrived at their final solution. CAPA-based, thermodynamics problems built confidence and expertise due to immediate feedback of correct/incorrect answers at intermediate solution steps.

5. The CAPA system analyzed each question according to the educational rubrics of "degree of difficulty" and "discrimination." Exams could then be constructed to distinguish students who understood fundamental concepts.
6. Faculty tools made it easy to monitor individual student diligence and success. By checking the data collected on the CAPA system, the professor immediately ascertained where students were having difficulty solving problems based on the current topic of study. Class time was then targeted to enhance student learning, review difficult concepts, and reinforce problem solution strategy before each exam.
7. Collaboration and originality was enhanced, with reduced opportunity for cheating. The nature of LON-CAPA problems address an issue that commonly plagues universities large and small: the problem of students keeping files of answers and passing them along to future classes, thus negating the learning value of assigned problems. LON-CAPA problems restore the learning value of homework problems. Since problems are individualized, class files from previous years must contain the process used for solving LON-CAPA problems. The student still has to solve the problems step-by-step, supplying the answers they calculate individually. Thus the files assist the instruction process rather than thwart instruction.

Conclusions and Future Goals

According to the instructor's experience piloting CAPA thermodynamics problems, students increasingly prove to be engaged with the concepts taught. While students were attempting CAPA problems, they would discuss the concepts and equations with their peers and the instructor before class began, adding valuable insights to classroom instruction. In contrast, when homework was solely assigned from the textbook, a less diligent student could simply turn in the answer, hoping the grader might overlook his or her lack of proper solution technique.

Our goal is to develop a full set of traditional as well as innovative, conceptual problems for engineering thermodynamics. In 2006, we plan to submit these thermodynamics problems to MSU for broad dissemination. The LON-CAPA system is open source and is available to public and private universities for a minimal licensing fee.

Another goal is to expand evaluation of CAPA for thermodynamics instruction. Criteria used for comparison will include the number of students completing homework, percentage of homework completed per student, number of questions generated in class, course averages, final exam scores, and the number of students dropping or repeating the course, etc. [7]. Numerous additional statistics will be gathered for each problem, e.g., number of attempts to achieve the correct answer, time from initial access until completion, etc. The quality of the problems developed also will be evaluated. As larger numbers of students use LON-CAPA tools for engineering, the statistics for the effect on student learning will expand.

This instructor believes that, with the addition of CAPA problems, students will master concepts with increasing rapidity, will increase their classroom interactions, and will demonstrate stronger course averages with greater success rates. With faculty and students more computer savvy than ever, CAPA thermodynamics problems provide a unique method for undergraduate instruction and a vital tool for professional education in engineering.

References

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Term Summary | Exit | Reload

Go to problem [1] [2] [3] [4] [5] [6]
1-6 Status: - - - - - -

Henk, Roy
Set 20, Due Tue, Nov 23, 2004 at 23:59

We will estimate the ideal performance of your neighbor's diesel generator, assuming that the engine undergoes an air-standard Diesel cycle with a compression ratio of 26.0. The air in the piston-cylinder is at 105. [kPa] and 15.0 [C] just prior to the isentropic compression process. The maximum temperature in the cycle is not to exceed 2200 [K]. For cold air-standard we assume constant specific heats at 300 [K].
Draw the *P v* and *T s* diagrams for the cycle.

The highest pressure in the cycle is:
`Answer:            [0/5 tries]`

The amount of heat transferred into one cycle is:
`Answer:            [0/5 tries]`

The work out of the isentropic expansion process for one cycle is:
`Answer:            [0/5 tries]`

The thermal efficiency of your neighbor's generator is:
`Answer:            [0/5 tries]`

The mean effective pressure (MEP) for the engine is:
`Answer:            [0/5 tries]`

The thermal efficiency of a Carnot cycle between the same temperature limits would be:
`Answer:            [0/5 tries]`

Figure 1. Example of a CAPA Homework Session with a Multi-step Thermodynamics Problem.

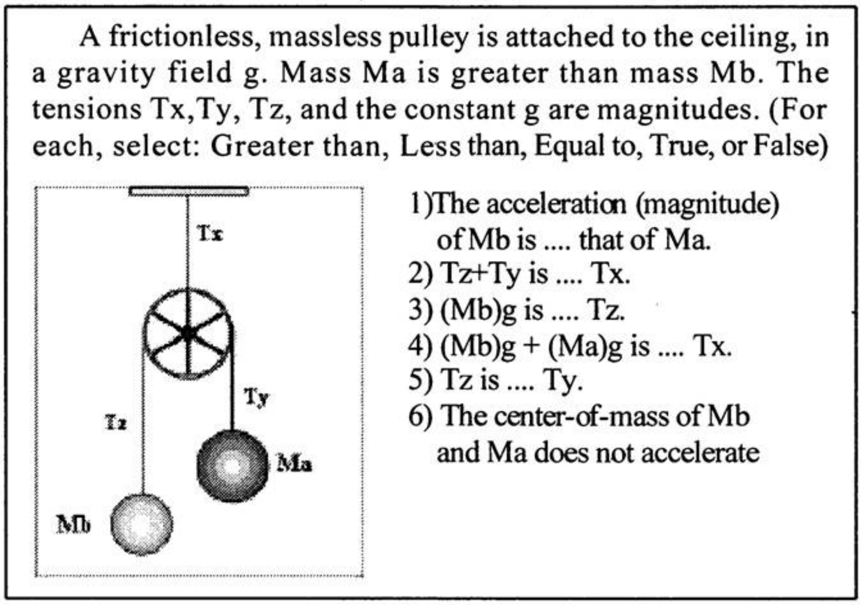

Figure 2. The MSU LON-CAPA team developed these six innovative conceptual physics problems (from Albertelli, et al., 2002).

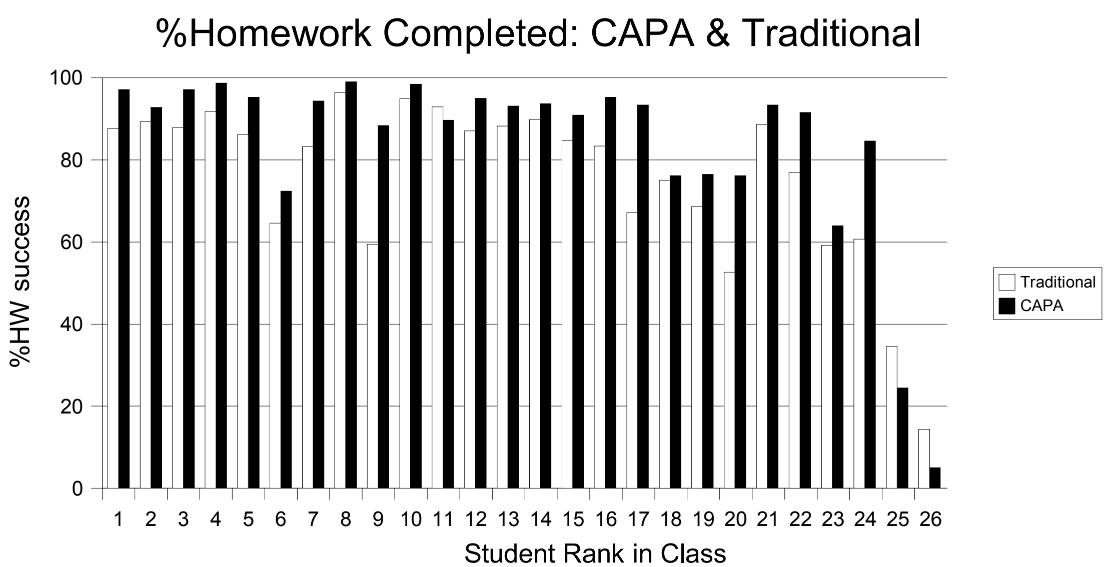

Figure 3. Successful completion of CAPA homework and traditional homework for each student in the class **(Fall 2004).**

ROY W. HENK is an associate professor in the school of Engineering and Engineering Technology at LeTourneau University, where he has taught since 2001. He received his B.S. in Engineering Science and Mechanics at Virginia Tech. He received his M.S. and Ph.D. in Mechanical Engineering at Stanford University. Prior to joining the faculty at LeTourneau, he designed aeroengines for Ishikawajima-Harima Heavy Industries (IHI) in Tokyo, Japan. His professional interests include thermofluids, experimental methods, combustor and turbine design. He is a registered professional engineer in the state of Texas.