Peer Tutoring in Web-based ConcepTests

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One of the most challenging problems in designing effective online learning materials is how to capture methods that work well in on-campus classrooms. Among these is the ConcepTest, which involves students explaining their conceptual understanding to each other. We have designed a way of achieving the same valuable learning objectives in an online environment by providing simulated social interactions through a gallery of student responses chosen from a previously collected library. Here we describe this method and show how it has worked very well in early testing. We suggest that this provides a way to bring peer tutoring into web-based courses and web-based course supplements.

The development of ConcepTests, originally promoted by Eric Mazur, has provided classroom teachers with a powerful method to help students internalize fundamental principles in physics. The method involves a sequence of activities, starting with the presentation of a well-designed multiple-choice question. Students are asked to commit to an answer (by writing the correct letter-choice down) without consulting their classmates. The instructor does not identify the correct answer at this point. Instead, the students are asked to defend their choices in exchanges with their neighbors. After a couple of minutes of discussion, during which the room is filled with a din of parallel conversations, the students are asked to vote on the same question again. The number of correct answers on the second vote usually exceeds the number on the first vote. At the end of the exercise, the instructor identifies the correct answer and explains the reason why.

The amazing thing about the ConcepTest sequence is that the instructor enters the cycle only at the very end. Students learn through peer instruction, as they describe their thinking to each other. This phenomenon exploits principles of socially facilitated learning that have been prominently promoted by Vygotsky and others. These are well-proven methods that are the foundation of active-engagement teaching. With the availability of personal communicators (clickers), ConcepTest teaching has become even more powerful. A histogram of the class distribution for each of the votes can now be easily displayed. This not only tells the students where their choices fit among their classmates, but it also provides the instructor with valuable feedback about how the method is working.

ConcepTests have been examined for their effectiveness by a number of educational researchers. Studies that deal with how to design ConcepTest questions are also available. Banks of questions and books are available as resources for teachers interested in adopting this powerful strategy in the classroom. It has been less clear how this instructional principle might be adapted to web-based courses and web-based course supplements. It has recently been demonstrated that the discussion phase of a ConcepTest sequence is the most critical component contributing to improved student understanding of the question. This is difficult to manage over a network. A chat utility is usually available as part of a learning management system (LMS). However, students who are in a chat discussion must be online at the same time. This compromises one of the advantages of web-based learning, which is that students can study any time of the day or night without synchronizing their activities with other students.

We have been developing web-based teaching methods that are modeled after strategies that work well under on-campus classroom conditions. One of the most effective of these developments is our use of simulated social interactions, which make it possible to include methods such as ConcepTests in online learning materials. Here we describe how simulated social interactions work and present encouraging results of testing with online learners.

The current structure of our system is built within LON-CAPA, a flexible LMS that was originally designed as an individualized, computer-delivered homework environment. However, the principles that we have identified can be easily adapted to most any LMS that is capable of handling a quiz. It is useful if the web pages comprising the online ConcepTest can be restricted to a sequence, so that students work through the pages in a predefined order.

Similar to how a ConcepTest is presented in an on-campus classroom, the online ConcepTest begins by presenting the student with a multiple-choice question. Upon submitting an answer, the student receives an image of a histogram showing how students voted on the same question in the past. In addition to the histogram, the student is presented with a text-entry box, and is asked to justify his or her choice with one or two sentences of text. When the student submits this justification, the LMS stores the justification, along with the student’s answer. The LMS then delivers a gallery of text responses, one for each possible answer, composed by students in the past. This appears on the same page as the student’s own response and a re-statement of the question. The student is asked to consider the response gallery and to then answer the question again. Upon submitting the second vote, the student receives a second histogram, along with an explanation of the correct answer. The all-important peer instruction step is replaced by the typed justification, provided by the student, and the gallery of responses, delivered by the LMS. This “simulated social
interaction” has proven to be very effective in helping students understand difficult ideas.

We construct the histograms from data acquired from students in on-campus classes, and from data acquired in prior use of the same question as part of online instruction. Under LON-CAPA, the particular response for a given answer can be randomly chosen from a group of responses that have been previously “qualified” by the course designer. After using a ConcepTest for awhile, a large library of student justifications accumulates. These are occasionally reviewed to update the gallery of responses that are available in the exercise.

We are currently using this method as part of online learning materials that were presented to students as a supplement to, as well as a replacement for, on-campus classroom learning conditions.13 The materials have been tested with students enrolled in a calculus-based introductory physics course at the Colorado School of Mines. In the most recent trial, students studied a unit covering work and energy through online lessons instead of attending on-campus classes. We presented the web version of the ConcepTests as an activity at the beginning of each lesson. Students received a “participation grade” for completing the activity. This is equivalent to an attendance grade received in an on-campus class.

Because of the programmed nature of the feedback delivered to the student in the middle of the activity, it is possible to create learning conditions that cannot be achieved in an on-campus classroom. One question that was particularly effective was the following:

A block slides from rest down a frictionless ramp of height $h$ and hits a carpet. The coefficient of kinetic friction between the block and the carpet is 0.9. How far does the block slide along the carpet?

- **A:** $h$
- **B:** Less than $h$
- **C:** More than $h$

In the initial vote 90% of students chose B. After the simulated social interaction, only 41% of the students chose this answer, while 56% of the students chose the correct answer, C.

Similar gains have been realized with other types of ConcepTests, including ranking exercises. Figure 1 shows an example of a ranking question from a standard resource.14

Only 17% of students identified the correct order in their first attempt. After considering a gallery of student responses, 56% of students were able to establish the correct order. In this type of activity, the gallery contained three responses, which were randomly selected from previously collected student responses that had been classified as correct, partially correct, and incorrect. Here is a typical gallery:

**Correct:** “The magnitude of the dot product of the force and $r$ are greater when they are in the same direction.”

**Partially Correct:** “I chose them by the displacement of the block.”

**Incorrect:** “The boxes are initially moving to the right, so the hand will need to do less work on the box if it pulls in the opposite direction.”

There are some distinct advantages to our online version of the ConcepTest, compared to what goes on in an on-campus classroom. The virtual partner, as represented by the gallery of responses, always provides a justification that goes with the correct answer. In a regular class the student’s partner may or may not understand things correctly. However, this advantage can easily turn into a disadvantage. If the question concerns a commonly held misconception, the response gallery will contain a justification that reinforces the misconception. Moreover, this justification appears in language composed by another student. This can be a powerful reinforcement of the misconception. So, it is very important to develop questions that minimize this potential confusion.

We were interested in learning about how the students perceived the feedback they received during the simulated social interaction. We used a five-point Likert scale (1 = strongly disagree; 5 = strongly agree) in a survey administered after the online course was completed. In response to the item “Other students’ responses from the database helped me to clarify my
thinking about the questions,” the average score was 4.1. Even more significant was the average score of 3.8, associated with the item “When I was reviewing student responses from the database it was similar to listening to other students in a classroom discussion.” These results show that online ConcepTests with simulated social interactions can be as effective as the on-campus classroom version.

In summary, we have developed a way of providing simulated social interactions that enable ConcepTests to be included in web-based instructional materials. The results of early testing of this strategy are encouraging and suggest that one of the most powerful classroom teaching methods can be adapted to online learning.

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References
13. An example of an online ConcepTest can be found at http://www.mines.edu/~truskell/OnlineConcepTests.html.

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