Using Web-Based Reading Assignments to Analyze Student Understanding

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In the introductory calculus-based physics class, we have begun to assign questions about the reading to be answered through WebCT. This enables us to monitor the degree to which students are indeed doing the reading before attending lecture. In addition, it provides information about how students interpret the information presented to them through the reading. We intend to analyze the results from student responses to reading questions assigned this semester, and to modify the questions we ask based on this analysis. In this paper we will discuss some of the responses we received to our initial set of questions and describe the process of analysis of these responses.

Introduction

In the past few decades, a number of research-based improvements to standard physics curricula have become available to instructors of introductory physics courses. Many of these improvements can be incorporated without significantly altering the overall structure of the traditional physics course. For example, a physics department might choose to substitute the University of Washington Physics Education Group's tutorials for a standard recitation section.[1] The tutorials are designed to match the sequence of instruction found in most introductory courses and to be completed in about the same time as is allotted most recitation sections. This substitution results in measurable improvements in students' conceptual understanding and usually slightly enhances problem-solving performance.[2] Similarly, the Microprocessor-Based Laboratories designed by Thornton, Sokoloff, and Laws[3] can supplant more traditional laboratories. These laboratories encourage more active involvement from participants and again result in better overall student performance. Finally, Eric Mazur's Peer Instruction[4] uses the time most physics courses use for lecture to encourage more active student involvement and to focus more explicitly on conceptual understanding. Instructors who have replaced traditional lectures with peer instruction have reported significant gains in conceptual understanding.

Three common features of the modifications listed above have contributed to their success. First, these are all research-based materials. Their authors have designed their curricula around what is currently known about common student difficulties with specific topics in physics. This has resulted in more effective use of the components of the course that are modified. Second is their incorporation of practices commonly advocated by education experts; more active student involvement, construction of knowledge by the student, and more effective use of student groups. Finally, because these curricula have been designed to replace one piece of a traditional course without drastically altering overall course structure, the likelihood that research-based materials will be incorporated by physics departments is enhanced, and the sustainability of the modifications becomes less dependent on individual instructors. Success with one modification may lead a physics department to adopt research-based materials in a second component of the course. Dissemination of reports of the effectiveness of these changes encourages their adoption at other institutions. In this way, significant and sustainable improvements to student performance on a national scale are possible through incremental improvements to physics programs that are facilitated by curricula such as those listed.

As described, research-based materials are available to improve the in-class components of introductory physics courses -- lecture, laboratory, and recitation section. We would like to similarly improve one of the out-of class components -- reading the textbook. We are in the process of creating a 'reader's companion', to be used in conjunction with a textbook, that shares the features of the modifications described above: 1) a solid basis in physics education research, 2) a transition to more active student involvement and construction of knowledge, and 3) adaptability without significant alteration to traditional course structure. In addition, the materials we are designing are intended to provide a new tool for conducting physics education research.

Others have recognized the value in promoting more active textbook reading in the introductory course. As part of his Peer Instruction, Eric Mazur requires that, prior to attending lecture, students submit answers to questions related to the reading. Similarly, Just-In–Time Teaching[5] (JITT) as employed at the Air Force Academy requires students to submit responses to an on-line 'pre-flight' that asks questions about the reading. Java-based 'physlets' that provide students with dynamic representations of physical situations are included as components of the assigned homework.[6] In these examples, the requirement that students respond to their reading has resulted in improvements in student performance.

We hope to extend the utility of reading assignments beyond what is described above by using them as a 'feedback' step in the development of curricula. We are analyzing student responses to questions about the reading and modifying the assignments to reflect our current understanding of student difficulties with the material. An iterative approach to curriculum development has been a key component of the development of effective curriculum such as *Tutorials in Introductory Physics.* The development of these materials has occurred in conjunction with research into student understanding. Much of what we have learned about the teaching and learning of physics in the past few decades is an outcome of this interplay between physics education research and curriculum development. *Curriculum development in this case is more than research-based; it is an extremely valuable component of the research process.*

First implementation of the reader's companion

We first attempted to implement the reader's companion in the Physics 215 course during the fall semester of 2001. This is an introductory calculus-based mechanics course, and most of the students enrolled in the course are engineering majors. During the semester, students were given 15 reading assignments, roughly one per week. To access their reading assignment, students logged on to the secure course web site that was implemented using WebCT[7], a commercial course delivery system that is used extensively at NMSU. The assignment detailed the sections to be read from the textbook and then asked students to respond to questions. There were between 3 and 5 questions per reading assignment. Students would type in their responses and press a 'submit' button when they were done. Within WebCT, a due date for the reading can be set after which the assignment was not accessible. (In practice, if students came up with an interesting excuse, the instructor emailed the questions to the students after the due date. This happened about 10 time s during the semester.)

Students were told that they would not be graded on the correctness of their responses, but that they would be given credit for submitting responses. This reading response counted for about one-eighth of their overall score for the course. The responses were saved by WebCT along with the student's name and information about the time the student had the quiz page open on their computer.

Encouraging students to read before coming to class

One benefit of the online reader's companion is that it can give some indication about whether students do the reading. Since the time spent on the quiz is also recorded, we had hoped that we would obtain information about how long students spent answering the questions as well.

Unfortunately, it seems commonplace for students to log on to the quiz and then walk away – times recorded ranged from 2 minutes 23 seconds to 85 hours, fifty-two minutes.

The white lines in Figure 1 show the percentage of students who submitted answers to the reading questions for the 15 reading assignments in the fall semester of 2001. (The lower line shows the percentage of students initially enrolled in the course and the lower line shows the percentage of students still taking the course examinations.) The participation rate drops off over the course of the semester from about 90% to about 60%. While we expect some drop-off as the semester progresses, we were surprised at how many students did not turn in the last assignments. It is possible that the turn-in rate could be maintained at a higher level if we were to provide more immediate feedback – as the semester progressed we fell behind in posting their credit for reading submission.

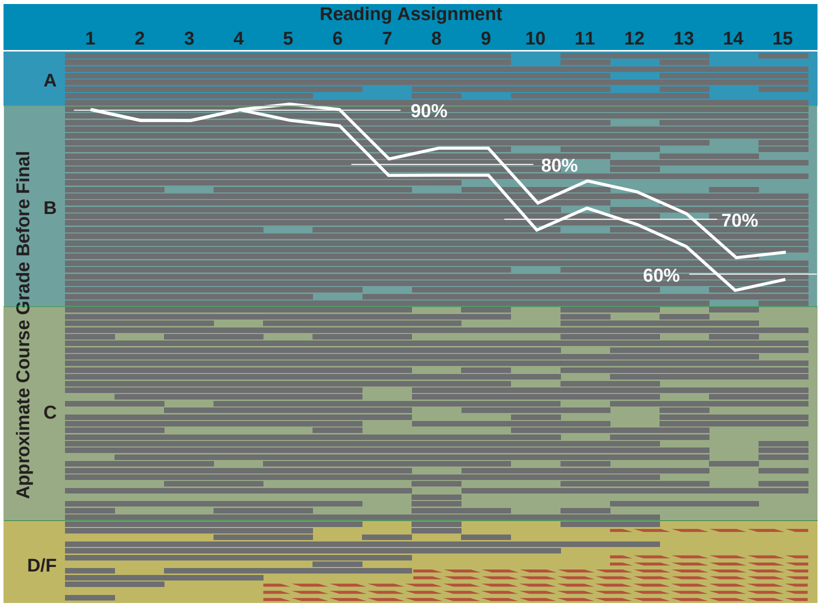

Figure 1: Reading Assignment Submissions.

Which students turn in the reading assignments? In the background of Figure 1, we have arranged the students by course grade just before the final examination (when this paper was written) in descending order. Each dark gray square represents a homework assignment turned in. As expected, the 'C' students do not do the reading as often as the 'B' students, and the D/F students have all but given up on the reading by the 9th assignment. The red striped bars indicate students who have effectively opted to take an 'F' for the course by no longer showing up for examinations. Overall, the 'A' students turned in 88% of the reading assignments, the 'B' students 92%, and the 'C' students 77%.

Use of the reading assignments as a physics education research tool

We give an example here of our analyses of student responses to the reading questions. The first question was asked as part of the fifth reading assignment that was completed before lecture on September 24th. Four questions were asked as part of this assignment on the topic of kinematics. Seventy-one students logged on to turn in responses to this assignment. Two students did not respond to a single question. (This is typical, and may be due to computer difficulties.)

One of the questions was " A ball is thrown straight up in the air. At its highest point, what is its velocity? What is the direction of acceleration at this point? Explain how you determined your answer." A correct answer to the first part of this question is that the ball is momentarily at rest at the top of its path, so the velocity is zero. Only two students gave incorrect answers.

The acceleration of the ball is downward, since the direction of acceleration is the same as the change in velocity vector for a small time interval around the instant in question. The change in velocity is found by subtracting a velocity vector just before the ball is at the top from one just after. Thus an upward vector is subtracted from a downward vector which results in a downward vector. Alternately, one could argue on the basis of dynamics instead of giving a purely kinematical response: The only force acting on the ball at this instant is the force of gravity, which acts downward. Thus the acceleration must be downward by Newton's second law.

Here are some examples of correct student responses, one using kinematics and one using dynamics:

> "At the highest point of the ball it is no longer moving up, and it hasn't started moving downward. There is no change in the position vector. This makes the velocity at the highest point zero. The acceleration at that point is the final velocity vector minus the initial velocity vector, and that would make the direction of the acceleration down toward the earth."

> "At the highest point the instantaneous velocity is 0. At that one single moment in time the ball has stopped. Acceleration is still pointing downward because of gravity. The acceleration vector doesn't change from the moment just after the ball leaves the hand until the moment just before the ball hits the ground (ignoring air resistance.)"

Thirty-eight percent (27 students) answered correctly that the acceleration was downward. We expected that many students would answer that the acceleration is zero since the ball has no velocity. This is a common misconception that has been well documented by physics education researchers. In fact, 28 students (39%) gave this answer. Here is an example:

> "At the highest point the velocity = 0. This is because the ball has lost all upward velocity. Since there is no velocity there must be no acceleration. So there is no direction of acceleration."

The next most common response was completely unexpected. Eight students (11%) answered that the direction of the acceleration was horizontal. Here are two examples of the reasoning underlying this response:

> "The velocity would be zero, because it stopped accelerating, and changed direction, so there is no acceleration. The direction of the acceleration would be a straight line because on the graph of this projectile, the tangent line would be a horizontal line."

> "The velocity is 0. The direction of acceleration would be East (Axi+0yi). As the ball gets to its highest point it would stop for a moment so it could change directions (straight down). This highest point would make a curve on a graph demonstrating the velocity. The tangent (which is acceleration) at the curve of the highest point is (Axi+0yi)."

These responses and the responses of the other 6 students are consistent with a misinterpretation of velocity-time graphs. The slope of a velocity –time graph can be used to find the magnitude and sign of acceleration in a given direction. However, it appears that these students are interpreting the horizontal line tangent to the top of the velocity –time curve for this ball as representing a direction *in space*.

The result we obtained above is precisely what we hoped to be able to use the reading assignments for – to discover how students are interpreting the information that is given them. The only thing that can be expected from student responses is the unexpected! Understanding the possible sources of confusion related to a specific topic in physics is an important first step toward the design of more effective curricula.

Summary

We have given an example of the use of research as a preliminary step in the design of curriculum. We emphasize here that without this research, the probability of correctly guessing student responses to physics questions such as the one described above is extremely small. Often the distracters chosen by physicists on multiple-choice exams, for example, bear no relationship to the ideas that students have. An understanding of specific student difficulties is essential to continuing improvement of physics instruction.

Our initial experiment with the use of reading assignments as a tool for education research was tremendously encouraging. Although the questions we asked were far from optimal, we have been able to use student responses to develop a better understanding of what students gain from the reading, and what difficulties they encounter in interpreting the given information. We will revise our question sets based on this analysis and in the future we hope to develop online intervention strategies that address common student difficulties.

References

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[6] W. Christian and M. Belloni, *Physlets: Teaching Physics with Interactive Curricular Material,* (Prentice Hall, Upper Saddle River, 2001).

[7] More information about WebCT can be found at www.webct.com.