AC 2011-1305: STUDENT REACTIONS TO ELECTRONIC LEARNING MODULES IN BME

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Abstract

The VaNTH ERC developed the CAPE/eLMS platform for electronic delivery of problems. The design goals for CAPE/eLMS were to provide a platform that was consistent with principles of the "How People Learn" framework, particularly more frequent and useful feedback to students than is often provided on traditional homework. At the same time, the system provides information to instructors on students' frequent errors, relieves the need to spend time on grading, and can provide practice on topics that are not easily done with pencil-and-paper assignments. The CAPE/eLMS system has been shown to provide benefits in vector analysis and free body diagram construction, but the extent to which the original goals have been met has not been fully analyzed across modules. As one component of that, we analyzed data from surveys included at the end of selected CAPE/eLMS homework problems used in biomechanics and physiology courses. Likert scales from strongly disagree to strongly agree were used for each question.

The pattern of responses was similar across problems. In response to the survey question: "I thought this was a useful homework problem," 50 to 70% agreed or strongly agreed for the 3 biomechanics modules investigated. A high percentage of students intended to return to these modules to review for exams. In the 6 physiology modules analyzed, the range of perceived usefulness was larger, with 30 to 85% of the students agreeing or strongly agreeing that different modules were useful. Two other survey questions: "I liked doing this problem on the computer rather than in the traditional way," and "Using the eLMS system helped me understand the concepts behind the problem" were significantly correlated with "usefulness." Within almost all modules in biomechanics and physiology, students who considered a module useful were those who preferred doing the module electronically and those who indicated that the electronic format helped them understand concepts.

Many students appreciate the usefulness of CAPE/eLMS modules, but differ considerably in their responses to the electronic format. Those who find it frustrating are apt to dismiss the utility of the module and those who are accepting of the electronic format tend to find the modules useful. This suggests that enhancement of the electronic experience itself could allow more students to recognize the learning benefits of this technology.

Introduction

The VaNTH Engineering Research Center in Bioengineering Educational Technologies (www.vanth.org) developed a platform for electronic delivery of problems consisting of an authoring component (Courseware Authoring and Packaging Environment – CAPE) and a delivery component (experimental Learning Management System - eLMS) that delivers problems to students and records their interactions [1, 2]. eLMS can be used in a course by linking it to the Blackboard Course Management System or creating specific stand-alone URLs. The overall design goal for CAPE/eLMS was to provide a learning technology platform that was consistent with principles of the "How People Learn" framework [3]. The CAPE/eLMS platform could be used for many types of on-line education. In bioengineering it has largely been used to date to deliver practice on difficult concepts such as vector analysis [4, 5], and to deliver homework with more frequent, timely and useful feedback to students than is often provided on traditional homework [6-8]. At the same time, the system was designed to provide several features useful to instructors, including automated grading and information on students' frequent errors. The CAPE/eLMS system has been shown to provide benefits in vector analysis [5] and free body diagram construction [4], but the extent to which the original goals have been met has not been fully analyzed across modules. Here we have analyzed data from surveys included at the end of selected CAPE/eLMS homework problems used in biomechanics and physiology courses. The goal of these analyses was to identify the types of problems that students find most useful, and to correlate features of the students' perceptions with their performance on individual problems and overall in the courses.

Methods

Homework problems implemented in CAPE/eLMS were used in two courses, a first level biomechanics course taken mostly by sophomores, and a physiology course taken mostly by juniors. The biomechanics problems have been discussed to some extent previously [7] and have only been modified slightly from the original versions. The physiology problems have been discussed briefly as well [6, 9]. All the problems had been used in courses previous to the current study, so most of the programming errors and confusions in language had been corrected. They are available for use at other institutions and information can be found at https://repo.vanth.org/portal/matrix.

Much of the homework in biomechanics is eLMS-based. Smaller problems build to three large ones, which are used to prepare the students for each of the three exams in the course. We added surveys to these three larger modules. In *Principal Stress*, students are given 6 questions about magnitudes of principal stresses and shear stresses and the angles of resultant forces when a rectangular block of material is loaded with several forces. In *Muscle Force*, anthropometric data about arm dimensions is given and the student is asked to calculate the muscle force needed to hold a weight in the hand at a particular location with respect to the body. If the student fails, he or she is asked to calculate moments and angles that will help arrive at the correct final answer, and finally, the student is asked whether the force is stabilizing or dislocating. The longest problem, which requires the student to use many of the concepts in the course, is *Diving Board*, which shows a diver part way along a diving board, and asks what the maximum tensile stress in the board is, and where this is located. As with *Muscle Force*, if a student cannot solve this, a set of questions of intermediate difficulty is used to guide the student to a final answer. As the last step, the student calculates the safety factor of the diving board.

The strategy for designing and using the physiology problems was somewhat different. The course that uses them covers renal, metabolic, endocrine and digestive physiology. The six problems analyzed here cover specific quantitative topics that students may have difficulty with in two areas: cellular transport and salt and water balance. Two problems, *Energetics* and *Calcium Balance* ask students to calculate on the basis of electrical and chemical forces, issues in ion transport. *Energetics* asks how much of the energy of a mole of ATP is used to power the transport by the Na/K ATPase. *Calcium balance* compares the ability of the Ca ATPase and the Ca^{+2}/Na^{+} exchanger to keep intracellular Ca low. *Urea* concerns the time required for intracellular urea concentration to reach 90% of the extracellular level after a step change in extracellular concentration, assuming passive urea transport and a given permeability. These modules are used before the first midterm exam. There are three salt and water balance problems. *Osmolarity* asks students to calculate the osmolarity of three fluids, 0.9% NaCl, lactated Ringer's, and normal extracellular fluid, and to reason about why the first two might be used as replacement fluids even though their osmolarity is not exactly that of extracellular fluid. *Seawater* is an extensive mass balance problem, in which the student needs to identify water and salt gains and losses on a whole-body basis, balance them, calculate a minimum urine volume, and reach a conclusion about whether it is feasible to drink seawater. *Salt and Water* does not involve calculations, but asks a student to identify hormones and organ functions that go into a feedback control diagram for extracellular fluid volume and sodium concentration. Students are guided step by step through this process, making choices about how blocks in the control diagram connect, what the inputs and outputs of blocks are, and what functions go into the blocks. Students use the salt and water balance modules before the second midterm exam.

In each of the modules described above, a brief survey was added at the end and the results reported here were obtained from those surveys. The questions in the survey are given in Table 1. Except for the time required to complete the module, the questions were all answered on a five point Likert scale, going from Strongly Disagree (1) to Strongly Agree (5). In the analyses, we grouped responses 1 and 2, and call this Disagree, 4 and 5, which we call Agree, and consider an answer of 3 to be Neutral. These allowed us to create histograms of student perception on the different survey items. We also correlated students's responses to one survey item to those on other survey items to determine whether, for instance, they liked the electronic format (survey item 5) more if they found that problem to be useful (survey item 1). In addition to the survey items, students had a free response block in which they could enter comments about their experiences with the modules.

Table 1: Statements used in the survey at the end of each problem. Students chose a number from 1 to 5 to indicate agreement with each statement, where 1 was strongly disagree and 5 was strongly agree.

	Survey Item	***Shorthand***
1	**I thought this was a useful homework problem**	**Useful problem**
2	**I plan to review my work on this problem before the exam**	**Plan to review**
3	**I thought this problem was difficult**	**Difficult**
4	**The eLMS system helped me understand the concepts behind the problem**	**eLMs helped understanding**
5	**I liked doing this problem on the computer rather than in the traditional way.**	**Electronic format**
6	**The problem provided some insight about the relevance of the course material to the outside world.**	**Relevance**
7	**How long did it take you to complete the problem?**	

In order to determine whether a particular student tended to view all of the problems the same way, or judged problems differently depending on the content or presentation, we computed the standard deviation of the each student's responses across modules in biomechanics or physiology. For example, if a student gave the same rating to all three biomechanics problems on the survey item "I thought this was a useful homework problem," the standard deviation for that student would be zero, whether his or her impression was uniformly positive or uniformly negative. If, on the other hand, a student's responses varied depending on the problem, the standard deviation would be higher, and had a maximum value that can be shown to be 2.3 for biomechanics modules, and 2.2 for physiology modules.

Results

Biomechanics

The survey questions fall into two categories. One category concerns the qualities of the problems themselves, including the usefulness of the problem and the intention of students to review their work before the exam. The data for these items for the biomechanics modules are shown in Figure 1. Between 50 and 70% of students found these problems to be useful (Figure 1A). The intention to review their work, Figure 1B, is another measure of usefulness, and more than 60% of students agreed that they intended to review their work before exams.

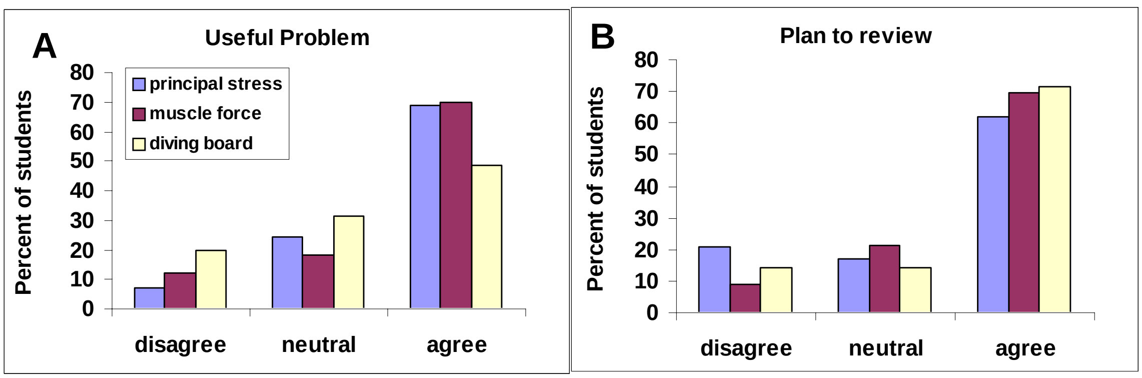

Figure 1: Survey responses for three biomechanics modules to two of the survey items. The number completing the survey was: 29 for Principal Stress; 33 for Muscle Force; 35 for Diving Board. There were 43 students in the class.

The other category of questions covers students' experience with the electronic delivery format. Responses to these questions are shown in Figure 2. Students had mixed evaluations of whether eLMS had helped them understand the content (Figure 2A), with about equal numbers agreeing, disagreeing, and being neutral on this point. The responses to the question about preference for doing the problem on the computer (Figure 2B) were somewhat more skewed, with no more than 30% of students agreeing that they liked this mode of delivery and up to 55% indicating that they did not. Because these two questions in Figure 2 were both about format, one might expect that responses to them would be positively correlated. This was true for *Muscle Force* ($R^2 = 0.38$; $p = 0.00013$) and *Diving Board* ($R^2 = 0.39$, $p = 0.0001$), but not for *Principal Stress* ($R^2 = 0.03$). For the same two modules, the responses to the usefulness of the module and the preference for the computer format were positively correlated (*Muscle Force*: $R^2 = 0.18$; $p = 0.014$; *Diving Board*: $R^2 = 0.26$; $p = 0.002$).

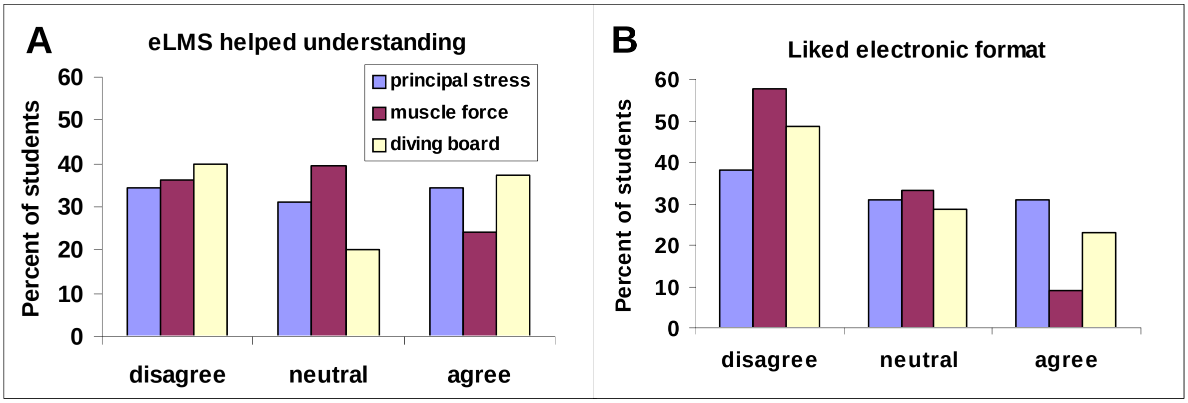

Figure 2: Survey responses to two questions about format of the problems. The number of students completing the survey is given in Figure 1.

Responses to the question about difficulty of the modules are shown in Figure 3A. Based on the comments, it appeared that the modules could be rated as difficult either because of content, or for reasons more related to format, for instance, clarity of the questions. For *Diving Board*, which was one of the most difficult, only 4 students commented on difficulty, and two said it was difficult because the questions were unclear, and two thought that the problem presented a challenging situation slightly different from what they had previously been asked to solve.

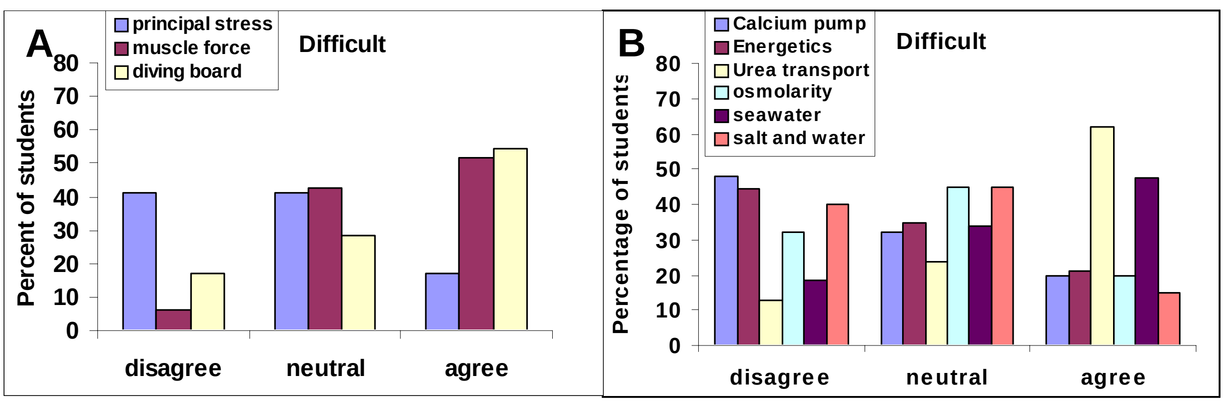

Figure 3: Survey responses to the statement that "the problem was difficult," for the biomechanics modules (A) and the physiology modules (B).

Physiology

Figure 4 shows responses to those survey items that concerned the usefulness of the problems (Figure 4A) and the intent to review before an exam (Figure 4B). The pattern is similar to that for the biomechanics modules, even though the physiology and biomechanics problems were authored by different instructors, and were structured somewhat differently. In general, the physiology problems were viewed as being useful by many students, although *Osmolarity* was rated poorly. *Salt and Water* was judged to be useful by 85% of the students, slightly off the top of the chart. This problem had two characteristics that were different from the other modules. It contained no calculations, and was entirely conceptual, and it was the only one of all the modules (in biomechanics as well as physiology) that was not graded, and was therefore optional. The number of students completing this module was less than half the number doing the other physiology modules. As with the biomechanics problems, the number who planned to review the physiology problems was generally about the same or slightly greater than the number who considered them useful. Only two of the physiology problems were regarded as being as difficult by more than 20% of the students (Figure 3B). These were the ones with more involved calculations, but, as with *Diving Board*, some students attributed the difficulty to a lack of clarity in the questions and others attributed it to difficult concepts.

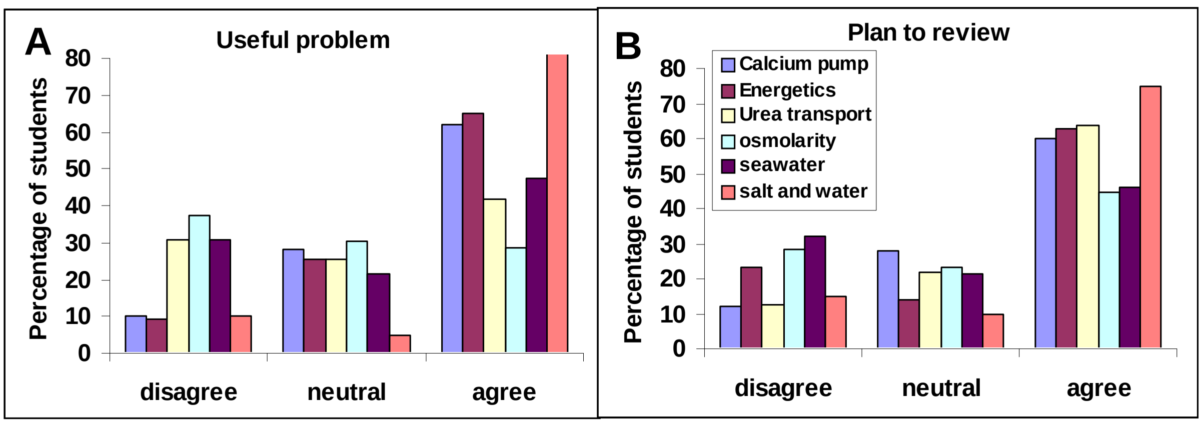

Figure 4: Survey responses to two questions for the 6 physiology problems. The number of students completing the survey was 50 for *Calcium Pump*, 43 for *Energetics*, 54 for *Urea Transport*, 56 for *Osmolarity*, 65 for *Seawater*, and 20 for *Salt and Water*. There were 59 undergraduates and 10 graduate students who used the modules.

Figure 5 shows responses to questions about the problem format. Again the trends are similar to those seen in the biomechanics modules. Roughly equal numbers of students fell into each category for most modules on the question of whether eLMS helped understanding (Figure 5A). As in biomechanics, the number who liked the computer format (Figure 5B) was lower than the number who found that eLMS helped understanding, except in the case of *Salt and Water*. This was the only module for which more than half of the students liked the electronic format.

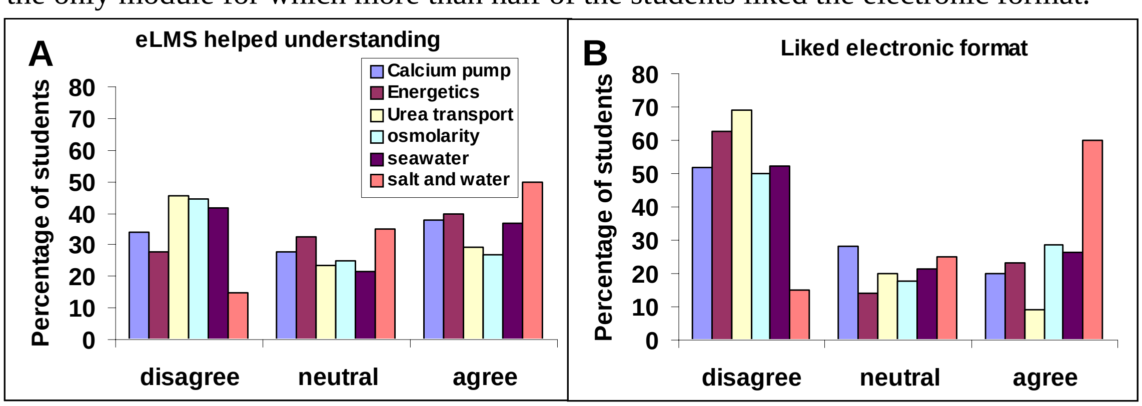

Figure 5: Survey items about format of the physiology problems. The number of students completing the survey is given in Figure 4.

As with the biomechanics modules, there were strong positive correlations for every module between responses to the two survey items shown in Figure 5, ranging from $R^2 = 0.35$ (*Energetics*) to $R^2 = 0.66$ (*Osmolarity*). All were highly significant ($p < 0.01$). That is, students who felt that eLMS had helped their understanding liked the electronic format, and those who did not feel that eLMS was helpful did not like this format. As in biomechanics, there were also significant ($p < 0.01$) positive correlations for every module between the usefulness of the module and the preference for the electronic format ($R^2 = 0.15$ for *Energetics* to $R^2 = 0.726$ for *Salt and Water*). The contrast with biomechanics was largely that additional positive correlations were observed between other survey items. The two items shown in Figure 4, which both relate to usefulness of the problem, were significantly correlated in all problems ($p<0.05$), which is not surprising. For 5 of the problems, difficulty was positively correlated with usefulness ($p < 0.05$) and for 4 problems, difficulty was correlated with eLMS aiding understanding ($p < 0.05$).

No individual survey item was correlated with performance on the modules or the relevant exam. There were weak but significant correlations between the sum of scores on *Calcium Pump*, *Energetics*, and *Urea Transport* and the score on Exam 1 ($R^2 = 0.067$; $p = 0.048$) and between the sum of scores for *Osmolarity* and *Seawater* and the score on Exam 2 ($R^2 = 0.22$; $p = 0.00015$). As noted in the discussion, these correlations do not prove that better performance on the problems caused better exam performance.

Standard Deviation Analysis

From the data presented in Figures 2 and 5, it is not possible to determine whether individual students tended to rate all modules the same way, or whether they liked some and disliked others. For two of the survey questions, we attempted to determine whether students were consistent in their responses across modules. Averaging an individual student's responses across modules did not answer this question. An average for each student would have provided information on this if students were always at one end of the scale or the other, an average response of 3,could have been generated by a student who was always neutral, or one who sometimes agreed and sometimes disagreed. Consequently, we computed the standard deviation of their responses, which is small for students who rated all modules similarly, and larger for students whose response varied depending on the module. Figure 6 suggests that the flat distributions in response to the question of whether eLMS improved understanding (Figures 2 and 5) did not occur because individuals always fell into the same bin. While some students are in the lower bins, most students felt that eLMS helped them understand some problems but not others, and this was true in both biomechanics and physiology. The pattern of standard deviations was different for the question of whether students liked the electronic format. For physiology, the average standard deviation was a little over 1, indicating that most students liked some modules but not others. In biomechanics, however, about a third of the class had the same opinion of all of the modules.

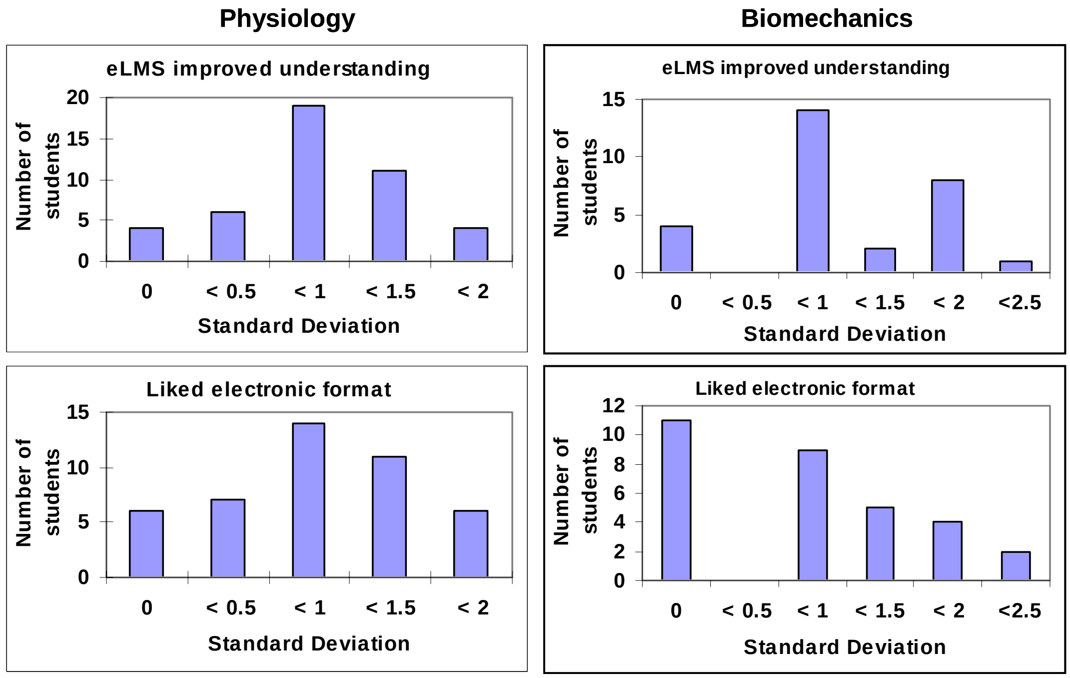

Figure 6. Standard deviation of each student's scores across the physiology modules (left) or biomechanics modules (right) on two of the survey questions. The bar at zero represents students who gave the same response about each module. The bar labeled "<0.5" indicates standard deviations between zero and 0.5 and so on. The maximum possible value of the standard deviation in this analysis was a little more than 2.

Discussion

One of the strongest findings is that students find the problems useful, which is encouraging, and motivates continued work. However, overall, they do not particularly like doing the problems on the computer, even when they acknowledge that the software has enhanced their understanding. We believe that one objection to the computer format is that it accepts only a preset range of values for answers, and cannot understand what the student "really meant," as opposed to what her or she entered on the computer. On each problem, students receive partial credit when they give some right answers and some wrong answers, but some are frustrated that they do not get partial credit on individual response items. One student, for instance, complained that in *Urea Transport*, he or she had used the correct method, but had made numerical errors. A teaching assistant might have awarded partial credit for the method, whereas the electronic system was able to recognize and graded the final answer. Interestingly, in this particular problem, students are first asked to choose an equation from several possibilities, before they are asked to calculate numerical values.

It was somewhat surprising to see the strong similarities in patterns of survey responses within the biomechanics and physiology modules and even between physiology and biomechanics, when the problems differ in many ways: different lengths, different complexities, different amounts of feedback, different numbers of chances to respond correctly, different topics. The similarity of patterns suggests that there might be modifications to the platform or to the strategy of programming problems that would be beneficial to students' experiences across modules. On the other hand, one can question whether there could be changes of universal benefit, because students are almost equally split on their view of whether eLMS helps their understanding (Figures 2A and 5A). The hope that improvement is feasible is based on the correlation between the perception of whether eLMS assisted understanding and the preference for the computer format, a correlation seen in all but one module. If we can move more students to recognize the features of eLMS that promote understanding (e.g. immediate formative feedback of appropriate type and amount), and make more effort to design those features into problems, we would predict that more students would like the computer format. Of course, students may find all types of homework frustrating, and not see the connection to learning, so it is unlikely that we will ever make them all happy, but there are steps we can take.

First, problems have to be very carefully worded so as not to cause confusion about what is being asked. Another important aspect is to be able to diagnose errors better, and provide more targeted correction. In some cases it has been possible to provide very specific feedback, and it would also be possible to provide different scores, depending on the type of error made. Another possibility is to allow students to see their sequence of work, as they can on paper, without stepping back through the previous screens, which some find frustrating. Occasionally students complain that they got a problem wrong multiple times, and never got a satisfactory explanation of how to do it correctly. Inclusion of the correct method and solution is present in most problems, but may need improvement in some modules. The data in Figure 6 suggest that there is not a single change that will improve all the problems, however, because individual students generally did not have a uniform reaction to all the problems in a course.

The data presented here were not designed to assess whether eLMS modules promote learning better than other forms of instruction, for instance, paper and pencil homework, or no homework at all. We found no correlation between survey items and performance on biomechanics exams, and only weak, although significant, correlations between module scores in physiology and exam scores. Little importance can be attached to these correlations or lack of correlations. It may be that the modules had little effect on strong students, but brought weaker students to a higher level before the exam. However, the exams test more than what students learn from the modules, and students have several sources of information when learning the materials and preparing for exams besides the modules. Separating the effect of the CAPE/eLMS problems from other elements of the course is very difficult and requires a different type of study. CAPE/eLMS has been shown to have learning benefits where this has been specifically tested [4, 5, 10]., and in general formative feedback is considered to be valuable. The modules also have the advantage over other types of homework that they grade themselves.

The success of the *Salt and Water* problem provides an interesting case. This module was not graded, so it was entirely formative with no summative component. It is possible to assign any of the modules and not use the score in a grade computation, but only provide it to the student for their information. If students were sufficiently motivated to use aids to learning at all times, this would be an ideal solution. However, only about a third of the students chose to use this module, and our experience is that students require an incentive to do the work. This module is also a good example of one that cannot be easily implemented in a non-electronic format, because it is made of many small questions that allow the student to gradually build the control diagrams.

In conclusion, many students appreciate the usefulness of CAPE/eLMS modules, but do not universally appreciate the electronic format. Those who find it frustrating are apt to dismiss the utility of the module and those who are accepting of the electronic format tend to find the modules useful. This suggests that enhancement of the electronic experience itself could allow more students to recognize the learning benefits of this technology.

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