AC 2011-743: BLENDING INTERACTIVE COURSEWARE INTO STATICS COURSES AND ASSESSING THE OUTCOME AT DIFFERENT INSTITUTIONS

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BLENDING INTERACTIVE COURSEWARE INTO STATICS COURSES AND ASSESSING THE OUTCOME AT DIFFERENT INSTITUTIONS

1. INTRODUCTION

It is increasingly appreciated that instruction should be learner-centered [1]. Various approaches have been pursued that include leveraging computer technology in effective ways and establishing more interactive classrooms. In particular, new approaches can draw upon the well-established principle that assessment should be integrated into the learning process [2]. For example, computer technology can integrate assessment by offering students individualized, timely help and feedback, which is known to improve learning [3-5]. Modern classroom-based assessments, such as minute papers, muddiest-point exercises, directed paraphrasing, and other classroom-based assessments [6], can give instructors insight into student progress. Here, we describe an instructional approach in which a single fine-grained assessment provides feedback to students and to instructors on student learning.

In particular, we present an "inverted classroom" approach to blending web-based learning materials into instructor-led statics courses. By using the web-based materials students receive initial exposure to a topic prior to class. Initial exposure outside of class typically leads to learning of basic ideas by many students, although they remain with questions or uncertainties regarding more complex or subtle ideas. Class time, which offers opportunities for deeper student-instructor interactions, can then be used, for example, to address students' remaining questions and more complex or interesting applications. To leverage student work on web-based materials prior to class, instructors need to track student on-line learning activities and identify the concepts and skills that students still need to master. In fact, the web-based materials are instrumented to record student answers, and provide the results in readily accessible aggregated form to instructors.

The paper reports on the experiences in blending the courseware into Statics courses at three distinct institutions: [redacted] and [redacted] offering a four-year BS engineering degree (the former private and the latter public), and [redacted] offering a two-year engineering associate's degree. We show how the same overall approach is plausibly adaptable at many types of institutions, while allowing for significant variation to suit different needs and preferences. We also report on measures of learning and student development, and seek to understand the impact of the materials and their blended use on students.

2. DESCRIPTION OF OLI ENGINEERING STATICS COURSE

The OLI Engineering Statics course, which has been described in more detail elsewhere [7, 8], is part of a suite of cognitively informed, web-based introductory undergraduate level courses that were developed under support by the William and Flora Hewlett Foundation. The course that has been developed by two of the authors ([redacted] and [redacted]) has benefited from prior research into conceptual knowledge in Statics and the psychometric analysis of the Statics Concept Inventory. It also incorporates many general lessons from the learning sciences that are broadly relevant, as described in previous papers presented by two of the authors at ASEE conferences. The following short description of OLI Engineering Statics course) repeats almost verbatim that presented in [9].

The course, freely available to individual learners and institutions, comprises a series of six units, each composed of a set of modules (eighteen in total). A module consists of a series of pages, each devoted to a carefully articulated learning objective that is independently assessable. Concepts, skills, and methods are explained using not only words and static images, which are typical of textbooks, but also through additional means which engage learners in active learning. Since an ultimate goal of the course is to apply Statics to genuine artifacts, developing competence in real engineering contexts, the course seeks to take advantage of digital images of relevant artifacts and video clips of mechanisms. Consistent with the authors' pedagogical philosophy of focusing initially on forces associated with manipulating simple objects, students are also guided to manipulate simple objects to uncover relevant lessons.

Non-interactive simulations, often involving motion, can be initiated by the student, and are analogous to in-class demonstrations. Motion is used extensively to convey basic concepts in Statics, consistent with the authors' pedagogical philosophy of making forces and their effects visible. In interactive, guided simulations, students adjust parameters and see their effects (what-if analysis). These are often initiated by a question which the student is supposed to answer. Simulations help learners connect calculations and numbers with physical representations.

Since Statics involves solving problems as well as understanding concepts, larger tasks have been carefully dissected and addressed as individual procedural steps. To help students learn procedures, we use several approaches. First, we explain the procedure in straight text, often with a worked-out example. Second, we demonstrate the application of the procedure with a "Walkthrough": an animation combining voice and graphics that walks the student through an example of the procedure. The effectiveness of such an approach is consistent with studies of multimedia learning, [15], since it engages both aural (hearing) and visual pathways, diminishing the mental load on each.

Students engage in problem solving procedures first in formative assessment "Learn By Doing" (LBD) exercises and later in summative assessment "Did I Get This?" (DIGT) exercises. These are computer-tutors in which students can practice the new skill as they receive detailed, individualized, and timely hints and feedback. DIGT exercises, located at the end of each page, assess whether the learning objective has been met. Most tutors offer the student the option of asking for a Hint at each step. There are sometimes successive hints: for example, a first hint that reminds the student of the relevant underlying idea or principle, the second hint that links the general idea to the details of the problem at hand, and a final hint virtually gives the answer away, but explains how one would arrive at the answer. Wrong answers at each phase provoke feedback. Depending on the question, feedback for an incorrect answer may be generic ("That's not right") or tailored to each incorrect answer, if a diagnosis of the error can be made.

Some computer-tutors offer scaffolding: the user can work independently towards the solution or request help, consisting of a series of sub-steps; at any time, the user can go back and try to answer the main question. All activities can be engaged several times by students; in some instances, multiple versions of a problem are generated with new parameters to enable further practice.

3. LEARNING DASHBOARD

Besides providing students with real-time assessment and feedback by means of interactive exercises, the OLI Statics course gathers information on students' on-line learning activities that instructors can use to inform classroom instruction. Student responses are recorded, aggregated, and interpreted in various ways for instructors in the form of a "Learning Dashboard". The instructor is given a high level view of student learning but also can drill down deeper into the data when more detail is desired. When instructors utilize the information to identify common student difficulties, classroom activities can be focused on specific concepts and skills that need elaboration and reinforcement. In this way, feedback to instructors from tracking student on-line learning activities allow the "inverted classroom" to reach its full potential. Here we describe the features of the OLI Statics course that provide the instructor with feedback on student learning.

3.1. Gradebook

A snapshot of the Gradebook is shown in Figure 2. It provides quiz scores of individual students, and checkmarks that indicate if a My Response feedback report has been submitted. Quizzes constitute summative assessments at the end of each module, with credit potentially awarded depending on the results. (By contrast, LBD and DIGT tutors are used purely for student learning and so do not feed into the Gradebook, although they are intended eventually to feed into the assessment stream that informs just-in-time changes of instruction described below.)

3.2 Detailed Quiz Reports

While an overall quiz grade itself is useful for awarding a grade, for instruction to reflect quiz results in an "inverted-classroom", the instructor needs to know how students answered individual quiz questions, at least in an aggregate way. OLI provides such feedback to instructors. As an example, an excerpt from the Module 7 Quiz Report is shown in Figure 3.

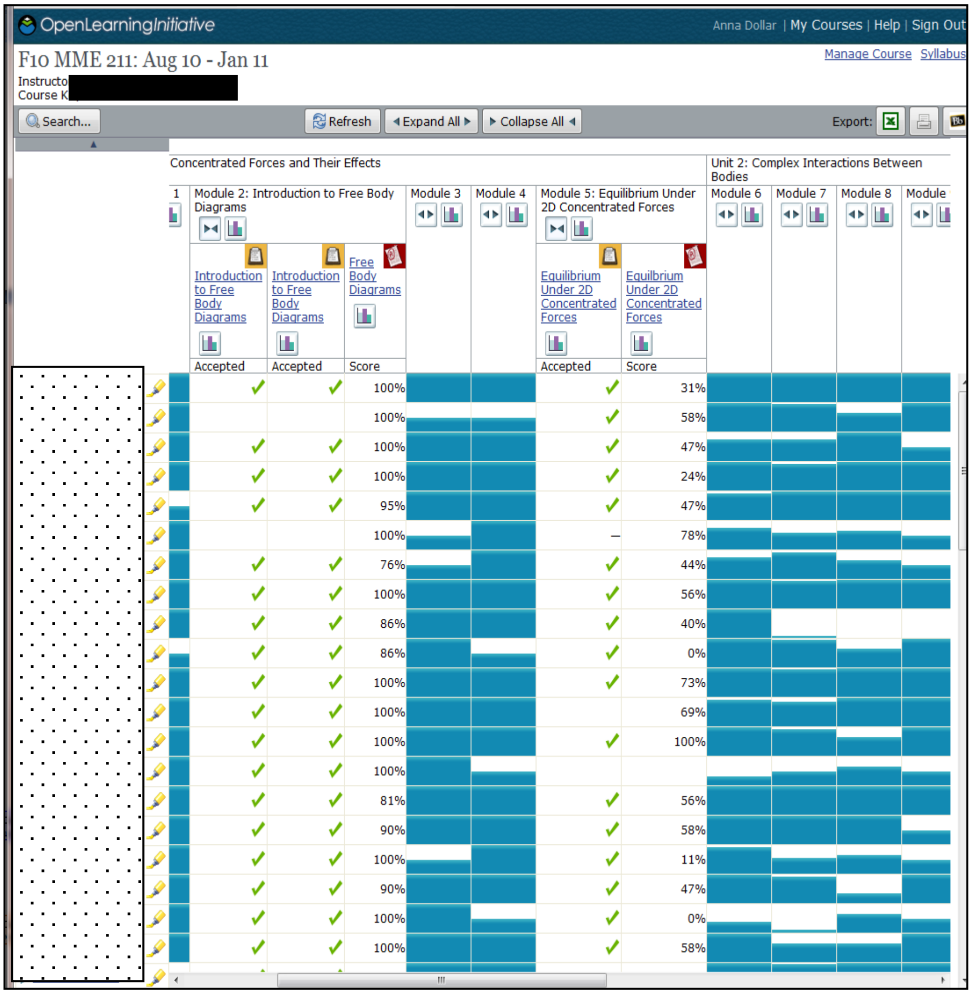


Fig. 2 Screenshot of Gradebook

Where did students make the most mistakes?

Question	Students	% Correct
Question 5	63	46%
Question 4	63	59%
Question 6	63	59%
Question 8	63	72%
Question 2	63	73%
Question 7	63	74%
Question 3	63	84%
Question 1	63	87%

Question 1

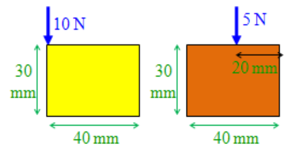
63 responses, 87% correct

fully equivalent
3

not equivalent
55

statically equivalent ☑
5

What is the correct description of the equivalency between the two loads shown below?



A. fully equivalent
B. statically equivalent
C. not equivalent

Back to Questions

Question 4

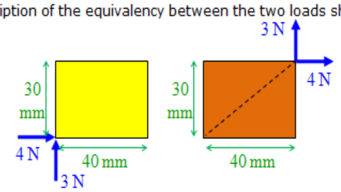
63 responses, 59% correct

fully equivalent
12

not equivalent
14

statically equivalent
37 ☑

What is the correct description of the equivalency between the two loads shown below:



A. fully equivalent
B. statically equivalent
C. not equivalent

Back to Questions

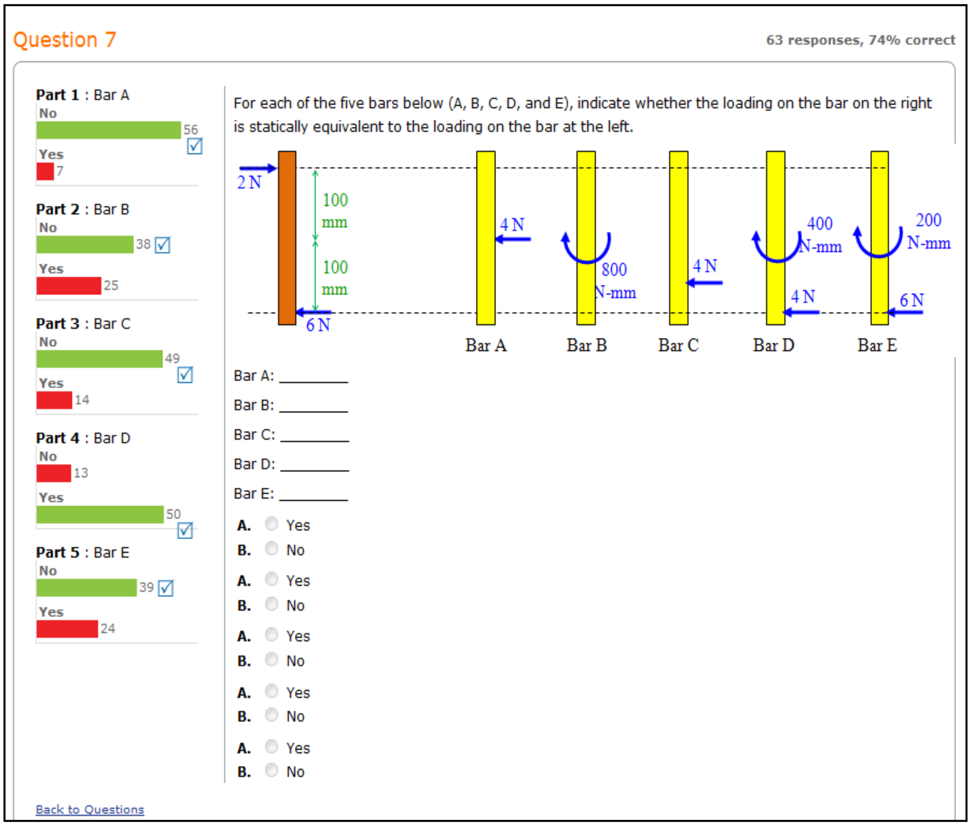


Fig. 3 Screenshots of Module 7 Quiz Report

3.3 Students' written feedback

At the end of each module students use the "My Response" link to describe what they found to be the most difficult points of the module, and questions they would like the instructor to address. A snapshot of the My Response Report from module 6 is shown in Figure 4.

Print | Close

Feedback on Introduction to Free Body Diagrams

as of 01/13/2011 10:28 AM EST   Show student names

Question 1 (Not required)

Sample: 68 responses

Enter your feedback here

Response
This was also a review, but it was a good one.
Still confused on labeling. Specifically why in Example 4 on the 'Procedure of Drawing' section in Step 4 Nab is 70 lbs
The practice really helped clarify what we're doing
This exercise was helpful in understanding but was a little unclear on the reasons why certain steps were taken.
This module was fairly straightforward and easy to follow.
I am confused as to when I should use the generic force (i.e. T sub c for the tension in the cable) or when I should use the actual weight measurement provided. I am following a pattern right now, but I do not understand the thinking behind the pattern.
I thought that most of this section was review from physics.
I love the interactive bits of this program. I think it helps A LOT with comprehension of the material. Only difficulty I had was identifying a force in one of the interactive examples, because it was about the force of E on D, but the option given was N(de) rather than N(ed) which was what I thought was the correct orientation.
I understand the material. Thanks.
The part of the quiz I had to think through was point #4.
The videos could have had a faster pace
Once again, I thought that this was a well planned tutorial and educational. The only parts I got confused on was why the legs of the table or supporting springs in the last "Did I get This?" were not included as points interacting with the subsystems even though they were touching.
I understand it. It did a good job of teaching me how to draw FBDs.
I have two questions for this module. 1. It asks us to outline the subsystem and treat it as one body. It then asks us to place a marker for the point of application for each block that makes it up. Why can we not treat it as one system, and put one point of application for the entire body? 2. For the 'Did I Get This?' part of the 'Procedure of Drawing Free Body Diagrams', why do the springs not play a role in the making of the FBD?
This quiz was much better because module 2 explained how to draw FBDs in a much easier manner. As far as I know I should have gotten all answers correct.
I did much better on this module than the last one. I do see progress in my understanding of FBD. But I still have a difficult time determining the proper point of application when one body is stacked on another body.
I did not have any issues but the section did make me further understand when and when not to use tension and spring calculations and earth calculations.
The hardest part was remembering that the weight of the bodies counted as parts of the FBD. Again, pretty basic though.
I think this was a very effective teaching method. Not only was it a strong learning tool because of the repetition, but also due to the step by step process shown.
i was a little confused on the last walk through example
I am understanding everything except how to determine the force in between two blocks or if there are multiple blocks on top of each other.
When looking at the session, I expected to finish it soon But, it turned out to be taking a longer time than I expected.. It is really fun.. I love it. By the way, is it enough to solve the problem as well as quiz on the website by now?(I mean should I try to solve more problems in the textbook as of now..)
No Problems
I understand this module and have no questions or conserns

Fig. 4 Excerpts from Module 6 My Response Report

3.4 Interactive Exercises Reports

Reports that quantify participation in individual interactive exercises for all the modules of the course are being developed. Thus far, only in modules 6, 7, 17, and 18 are all student activities in the interactive exercises recorded. The reports quantify overall class use of interactive exercises aggregated across all students in the class, and are similar to quiz reports. These reports have not been yet analyzed.

4. BLENDING OLI COURSEWARE INTO A COURSE: AN INVERTED CLASSROOM STRATEGY

The “inverted classroom” [10-11] has been proposed as one means of better utilizing limited class time and promoting a more learner-centered environment. In an inverted classroom students study on-line material prior to class, and so come to class prepared. Then, class time can be devoted to more engaging, learning-intensive activities, rather than to routine presentation of basic material. The inverted classroom can be particularly effective if instructors monitor their students’ preliminary learning, and identify those concepts or skills that students find challenging. Then, learning-intensive classroom activities can be chosen appropriately. Thus, the inverted classroom differs substantially from the traditional model in which students come to class unprepared, listen passively when the instructor lectures on the new material, then "learn” the material on their own, and finally are assessed by mean of quizzes and exams [11]. Two of the authors reported in [9] on the experience of using an inverted classroom strategy in the F09 semester.

Recently, at all three institutions where the authors teach Statics, OLI was incorporated following the inverted classroom approach. Students were assigned to work on one or more OLI modules prior to class. Prior to the due date, students were to complete the end of module quiz, and to use the “My Response Link” at the end of each module to indicate concepts and skills that were most difficult, and questions they would like addressed in class. Thus, initial exposure and learning occurred on-line prior to class, Because assigned modules were to be completed several hours prior to class, instructors had time to review performance on the OLI quiz (by question) and to read through student feedback from “My Response Link”. Class activities were then adjusted to address specific topics, concepts, and skills that required extra attention, particularly when many students did poorly on a quiz question or reported having difficulty with the same concept or skill. When only one or two students reported having a difficulty, the instructor would send a clarifying response to those individual students. In the future, the overall OLI system will monitor increasing numbers of student activities within modules, thereby generating even more meaningful and actionable feedback to instructors.

5. PARTICIPANTS AND DATA COLLECTION

5.1 Participants

The [redacted] participants in this study were 117 college students, nearly all mechanical engineering majors, who were enrolled in a lecture-based, semester-long statics course in the Department of Mechanical Engineering in Fall 2010.

The [redacted] participants were 64 college students who were enrolled in a lecture-based, semester-long statics course in the Fall 2010. There were 32 mechanical, 11 management, 4 computer, 3 chemical, 3 electrical, 1 manufacturing, 4 general engineering, 1 bioengineering, and 5 non-engineering majors.

[redacted] participants were 30 college students evenly mixed between mechanical, civil, chemical, and electrical engineering majors who were enrolled in the “May-mester” 14 day intensive block class during May 2010. The class was mixed method between project-based learning, OLI driven question/answer sessions, and problem solving. OLI, daily learning reflections in a journal, and project work comprised the out of class assignments. Lecture made up less than 15% of the class.

5.2 Data Collection

OLI data

At [redacted] and [redacted] students were assigned to work through the OLI Engineering Statics course materials at a pace of one to two modules per week. At [redacted] students were assigned one OLI module per night. Scores on the OLI end-of-module quizzes were recorded.

At [redacted], OLI quizzes and completion of My Response Feedback reports together comprised 1.67% of the final grade, At [redacted], OLI quizzes comprised 5.4% of the final grade (with no credit for completion of My Response Feedback). At [redacted] the OLI quizzes, as well as completion of My Response Feedback and the modules themselves, were strongly emphasized day after day, but were not calculated into the final grade. The final grade was dependent only the student's ability to provide evidence of overall learning at the end of the course.

Thus, at all three institutions there was only a modest grade incentive or no grade incentive to score well on the OLI module quizzes, and the vast majority of OLI module activities (LBD's and DIGT's) constituted only a tool for learning and contribute nothing directly to grades.

Statics Concept Inventory (SCI) Results

Near the end of each course students took the Statics Concept Inventory, a widely-used, well-validated test of conceptual understanding of Statics [12-14]. As reported in [13-14], relatively high correlations have been found at many institutions between scores on the SCI and scores on in-class exams. As one means of judging the level of correlations that might be expected between the SCI and class-based performance measures, correlations between different class exams within a course were also calculated, and found to range from $r = 0.32$ to 0.73 [13].

Summative Course Performance

For a summative measure of performance in class, we have used the mean of in-class exam scores in the case of [redacted] and [redacted], and the final grade (A, A^-, B^+,…) rendered into a numerical scale in the case of [redacted].

Paper Homeworks

Written homework problems were assigned nearly every week at [redacted], and [redacted], and the written homework scores were recorded. The amount of homework is correspondingly less than in typical courses, because students spend time working through OLI modules. The contribution of written homework to the course grade, like that of OLI, was rather small: at [redacted] pencil and paper homework (not related to OLI) comprised 3.33% of the final grade; at [redacted], pencil and paper homework (not related to OLI) contributed 8.6%. There was no paper homework in the [redacted] course.

Perception Surveys: We surveyed students at [redacted] and [redacted] regarding their perceptions of the feedback offered by OLI and the feedback that is typical of other courses. Students responded, according to a scale of Strongly Agree, Somewhat Agree, Somewhat Disagree, Strongly Disagree, to a series of six pairs of questions, as follows:

1-2. The feedback I receive **from OLI / in a typical course** on my work is understandable.
3-4. The feedback I receive **from OLI / in a typical course** tells me what I did right or wrong and why.
5-6. The feedback I receive **from OLI / in a typical course** helps me learn.
7-8. The quantity of feedback I receive **from OLI / in a typical course** is (answer choices: too little, just right, too much)
9-10. The professor, **using OLI / in a typical course**, is aware of where students are doing well and where they are having difficulty.
11-12. The professor, **using OLI / in a typical course**, addresses topics in a way that is targeted/tailored to what students need.

The survey was completed by 75 of 107 students at [redacted] and 41 of 64 students at [redacted].

6. RESULTS

6.1 Performance

In [15], the numbers of in-module activities (LBD's and DIGT's) that students engaged in and their performance on paper and pencil diagnostic tests covering material in each module (forerunners of the present end-of-module quizzes) was studied. First, it was found that the scores on diagnostic tests increased markedly after using modules in comparison with pre-test scores. Second, it was found that students who engaged in a moderate to large number of activities had significantly higher scores on the diagnostic tests. Based on the data, it was proposed that students who self-regulated in their choice of in-module activities tended to have better learning outcomes. Thus, engaging in OLI activities appears to contribute to learning.

Here we consider a different question: whether performance on OLI as the semester proceeds could be an indicator of higher stakes class performance, such as exams and final grades, or of conceptual understanding. To that end, we determined Pearson-correlations between the mean OLI quiz scores and the summative course performance measures identified above and the SCI. The results are presented in Table 1.

Table 1. Pearson Correlations at three institutions between mean OLI quiz score and performance in course (exams at [redacted] and [redacted], final grade at [redacted]) and on Static Concept Inventory.

	OLI Quizzes- Course Performance	OLI Quizzes-SCI
[redacted]	0.61	0.49
[redacted]	0.80	0.74
[redacted]	0.45	0.49

Indeed, the evidence suggests that quiz scores in OLI Statics might be used as an early warning signal regarding final course performance and conceptual understanding.

Since performance on written homework might commonly be taken as an indicator of course performance and learning, we measured the correlations between homework scores and the same outcomes. The results are presented in Table 2.

Table 2. Pearson Correlations at two institutions between mean homework score and performance in course exams and on Static Concept Inventory.

	Written Homework- Course Performance	Written Homework -SCI
[redacted]	0.33	0.18
[redacted]	0.26	0.22

It can be seen that written homework scores correlate with outcomes much less strongly than do OLI quizzes. It should be stated that homework at [redacted] is assigned in a way that demands student self-regulation. Solutions are provided (in a separate file) simultaneously with the homework problems, and students are graded only on effort, not on the correctness of answers. Thus, the potential benefit of homework is entirely left to students: they may truly gain something from working on the problems, or can gain nothing and practically copy the answers (from solutions or fellow students). Thus, the low correlation with homework scores and outcomes is not surprising. At [redacted] written homework was graded by a grader, and the solutions were posted after the due date.

6.2 Perceptions

From the survey results for questions 1 through 4, which address whether the feedback they receive is (1) understandable, (2) indicates what is right and wrong and why, (3) helps them learn, or (4) is sufficient, students report little difference between OLI and typical courses.. This result was surprising; we know for certain, that the *amount* of feedback *available* in OLI is significantly greater than what students receive in typical graded written homework. But, amount of feedback available does not translate necessarily into what students actually use, let alone what makes sense to students and what helps them learn. We also note that this survey has not been used before, and it clearly has not been validated. Even though the preamble to the survey tries to explain what is meant by "feedback", the questions may have been ambiguous to students.

Results for questions 9-10 and 11-12, which pertain to the instructor's role, are shown in Figures 5 and 6. Students do report different levels of agreement with the statements in these questions regarding OLI and typical courses. To determine whether the difference is statistically significant, a chi-squared test was applied to determine how likely it was that frequencies of responses corresponding to OLI and to typical courses were different merely due to chance. Results of the chi-squared tests are also shown in Table 3. In the case of [redacted], the probability that these differences are due to chance is vanishingly small.

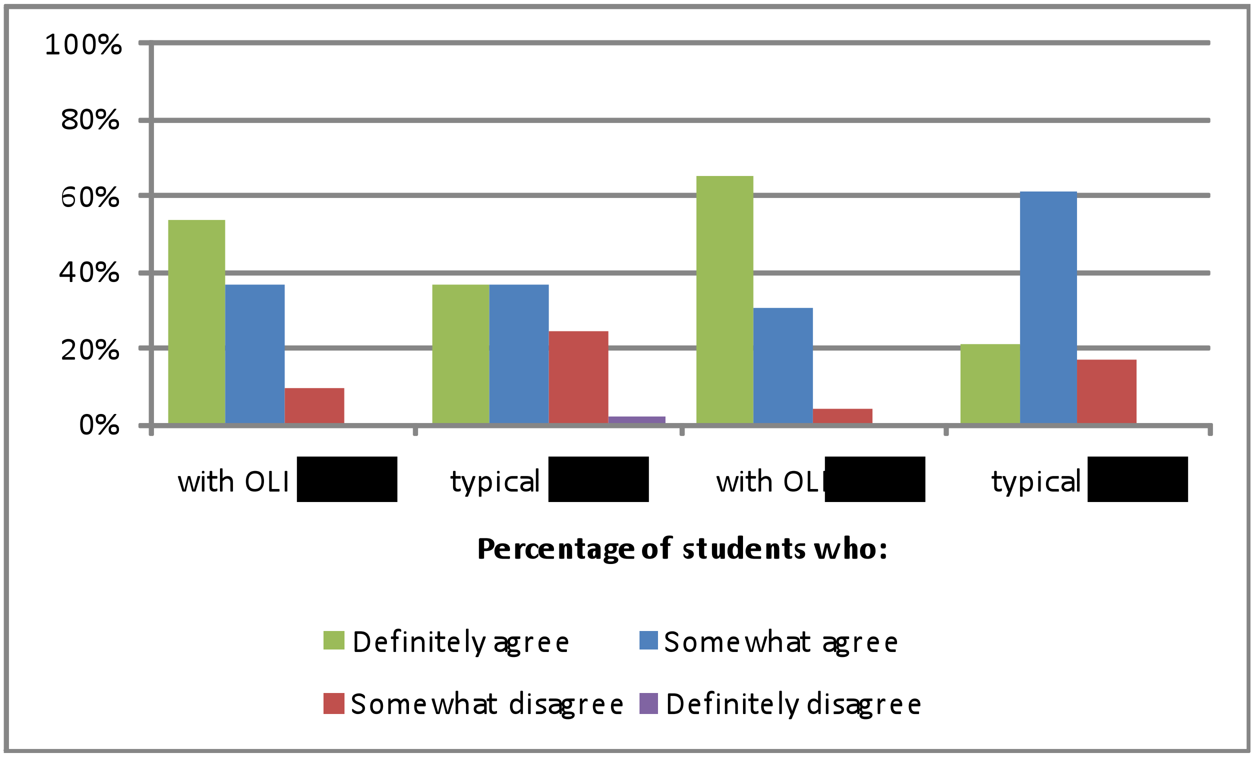


Fig. 5 Results of responses to survey questions 9-10: “The professor, using OLI / in a typical course, is aware of where students are doing well and where they are having difficulty”.

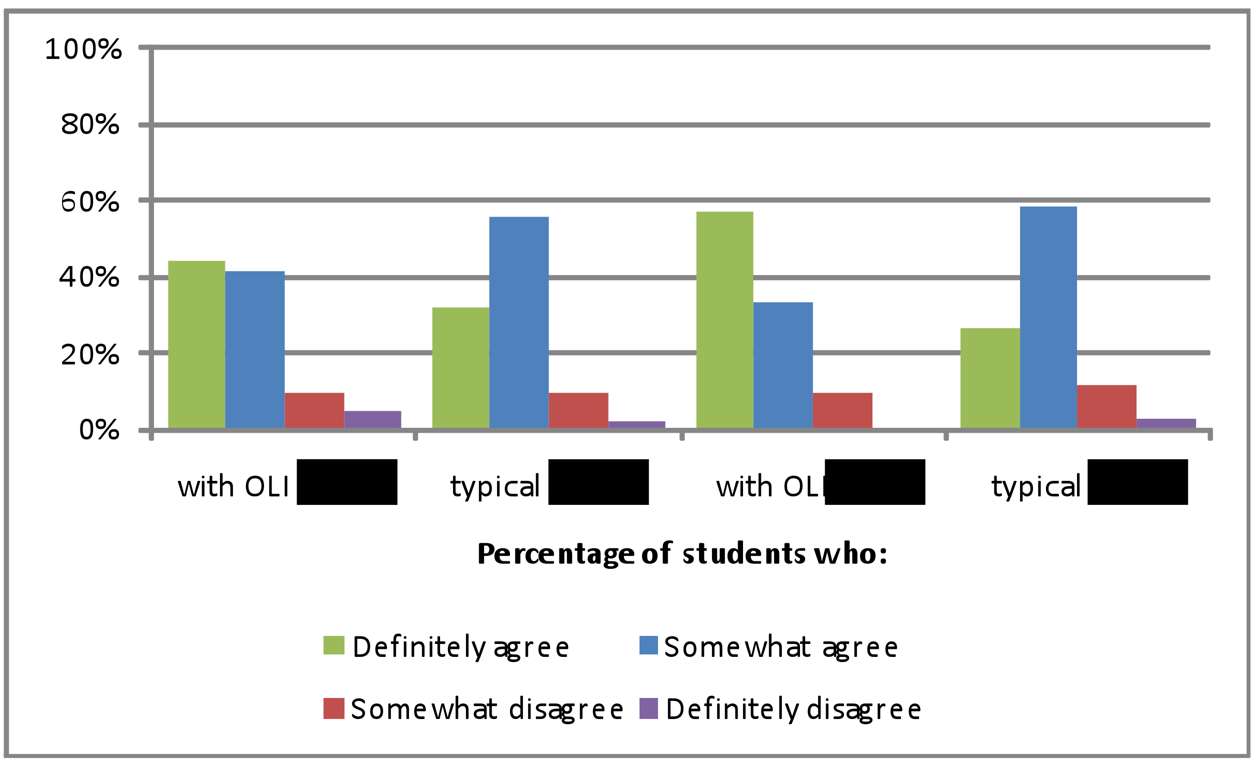


Fig. 6 Results of responses to survey questions 11-12: “The professor, using OLI / in a typical course, addresses topics in a way that is targeted/tailored to what students need”.

Table 3. Results of Chi-squared test for significance of difference between responses to pairs

	Instructor Aware (Questions 9-10)		Instructor Addresses Topics (Questions 11-12)	
	χ^2	p	χ^2	p
[redacted]	30.671	< 0.001	13.854	0.001
[redacted]	3.884	0.143	1.694	0.429

In summary, given their high correlations with both course performance and a standard measure of conceptual knowledge, OLI quiz scores may ultimately be used by instructors and students as an early warning sign that a student is at risk in a statics course. And, while students may not view the feedback offered by OLI as significantly different from that given in typical courses, they may see value in their instructors using that feedback to improve learning in the classroom. Both of these findings need to be studied in greater depth. But, these results should start to give encouragement to instructors who worry that on-line learning will render them obsolete.

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