# USING A DIGITAL DASHBOARD FOR LEARNING TO BLEND INTERACTIVE, WEB-BASED COURSEWARE INTO AN INSTRUCTOR-LED STATICS COURSE

### **1. BACKGROUND**

### 1.1 Need for Improving Assessment-Feedback Loops

In response to an increasing appreciation that instruction should be learner-centered [1], various learner-centered instructional approaches have been pursued. These have included both leveraging computer technology in effective ways and establishing more interactive classrooms. Still, many engineering subjects continue to be taught in a traditional, top-down fashion, with one-way communication from the lecturer, and textbook homework problems that are solved outside of class, on which delayed and minimal useful feedback, if any, is given.

Improvements should be based on the major lessons from the learning sciences, for example that that assessment should be well integrated into the learning process [2]. Perhaps the greatest opportunity that computer technology can exploit is associated with offering students individualized and timely help and feedback, which is known to produce improved learning outcomes [3-5]. In traditional courses, the delay in feedback on homework can frustrate students who are attempting homework when help is unavailable, and can also leave students unaware that they have serious deficiencies until exam time. By contrast, on-line materials can let students see immediately that progress is insufficient and point to additional learning resources.

Traditionally, instructors' insight into student progress comes from homework and exams scores; while potentially valuable such information and the associated feedback is sometimes too late to be of significant use. Researchers have also developed in-class assessment techniques, such as minute papers, muddiest-point exercises, directed paraphrasing, and other classroom-based assessments [6], which are fast compared to fully graded assignments. Instructors can pose a question (usually multiple-choice) for students to respond to [7], and with personal response systems, or "clickers", collect each student's response automatically, and view the class's distribution of responses *in real time*; such input can be valuable to students and instructors. With an on-line learning resource, it is possible to go a step further: to draw data from multiple exercises and analyze them by concept or skill, assembling a fuller picture of student learning.

Figure 1 (adapted from Marsha Lovett, CMU) depicts how information on learning activities can pass between students and instructors so as to further the learning process. There are potentially two loops of learning, assessment, feedback, and re-engagement in learning: one involving the student and another involving the instructor. When the student and instructor feedback loops are uncoordinated, instructors waste effort in generating feedback that students cannot (or do not) use, e.g., students only glance at graded homework because they have already started the next topic. By contrast, learning in the classroom may be much greater if feedback loops are synchronized: instructors adjust their teaching and generate feedback that students actually use to refine their current understanding.



Fig. 1 Schematic of Assessment- Feedback Loops for Learners and Instructor

# **1.3 Inverted classroom**

While students are passive in traditional lecture-based courses, classrooms can have students actively engaged, which is known to improve learning outcomes [8]. In a study of results from many physics courses, Hake [9] showed that courses in which instructors applied active engagement techniques had greater normalized gains on the Force Concept Inventory [10] than courses with a more traditional lecture-based approach. There is a great opportunity to fully utilize the limited class time and promote a more learner-centered environment.

In an "inverted classroom" [11-12] students study on-line material prior to class, and so come to class prepared. Then, class time can be devoted not to routine presentation of basic material, but to more engaging, learning-intensive activities. 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 [12].

# 2. DESCRIPTION OF OLI ENGINEERING STATICS COURSE

The OLI Engineering Statics course, which has been described in more detail elsewhere [13, 14] 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 comprises a series of units, each composed of a set of modules. 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. DIGITAL DASHBOARD FOR LEARNING**

As described in Section 2, the OLI Statics course provides students with real-time assessment and feedback by means of interactive exercises. To engage the instructor more fully in the learning process, OLI seeks to provide information on students' on-line learning activities to the instructor who can then utilize that information to benefit classroom instruction. To that end, the server on which the OLI courses run records student's responses. These responses will then be aggregated and interpreted in various ways and made available to the instructors on the OLI courses web sites in form of a "Digital Dashboard for Learning".

A general principle in constructing the dashboard is to provide a high level view of student learning, unobscured by details, but also to allow the instructor to drill down deeper into the data

when such detail is desired. The instructor can display and discuss in class those concepts and skills that might have caused the most difficulty. In addition, when appropriate, the instructor can determine which students did not meet particular objectives and potentially offer them remedial instruction.

When instructors utilize the information to identify common student difficulties, they can then focus classroom activities on specific concepts and skills that need elaboration and reinforcement. A real-time feedback loop to instructors from tracking student on-line learning activities would bring the "inverted classroom" to its full potential.

# 3.1 DDL features currently available for OLI Statics

Here we will describe the features of the course that provide the instructor with feedback on student learning that were available for OLI Statics in the fall of 2009.

A snapshot of the Gradebook is shown in Figure 2. With this view, the gradebook provides information on which pages each student has visited. One can expand, for example, module 1 of unit 1 to view its individual pages. More information is available in the Gradebook excerpted in Figure 2 on modules 6 and 7; only for those modules were online quizzes available in the Fall 2009 semester.

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Fig. 2 Screenshot of Gradebook

At the end of each module via the "My Response" link students can describe what they found to be the most difficult points of the module, and a major question they would like the instructor to address. A snapshot of the My Response Report from module 6 is shown in Figure 3.

Student	Response
	I thought there were definitely some parts of this module that were hard and then other parts that weren't too bad. What I had the most trouble with was determining the moment. On a couple problems I would try it, get it wrong, and then ask for a hint and once I got the hint I couldn't figure out how they got that answer. On one it found the moment from the forces in the x and then in the y, but for the forces in the x it added both of them togetherneither one was negative and I didn't understand why. Other than that I think I improved as I went, especially when a lean by doing would have 5 questions so I could find my mistakes and figure out how to do all the different problems.
	it was difficult to understand the effects the hand plays in role with the couple if the forces are rotating in the same direction or also how the different pegs had different forces being applied to them and understand what will happen.
	This was a very interesting module. I think this was one of the first that i actually liked because there were so many learn by doing exercises.
	I still think I can use one finger to rotate the faucet. Does it cause by the friction or what? I can physically do that, but I can not explain it. Also, it encounters the content in this module. Secondly, could I make the the clockwise as the positive sense instead of the negative on as it shows here? Thirdly, I think I found a mistake in EXAMPLE: Quantifying Couples 5. It forgets to mention the force E involved in order to for me to find another correct force to balance forces A,b,c,d and E.
	The most confusing part of this module for me was under "Quantifying Couples". I understand why the Couple Moment can only occur when the net force is equal to zero and when there is a perpendicular distance between the two opposite and equal forces. But, I don't understand the concept of balancing the blue "L-shape" with the yellow peg. I also was confused in the demo when there were 8 lb in the east x direction and two separate vectors (5 and 3) in the west x direction. Clearly, the sum of forces in x equals zero because the 5 and 3 add up to 8, but i don't know how to use the F1d1 equation in this circumstance. Without that, I couldn't know what force to apply to the yellow peg for balancing the couple. Does balancing the couple mean to stop the rotation by exerting the same moment in the opposite direction?
	It can get hard to identify and system as in equilibrium when there are so many forces. Does is make sense to choose the point to calculate the moment about, to be a point without any forces, so the moment is the same for every point on body?
	This kind of rotation is a completely new concept for me but i was able to understand it fairly well by the end of the module. I was getting too caught up in thinking about moments which threw me off at the beginning
	This module was pretty straightforward, the only part that I missed was the Representing hand as a couple sometimes, but reading back through problems it makes sense.
	This module is just confusing. The ideas behind the materials make sense but seeing where to take the moment from and what the distances are get confusing with more and more forces in the diagrams. Going through the 'Did you I this' exercises definitely helped towards the end putting everything together into one problem.
	I thought that overall, this module was simpler than module 5 was. It was easier to understand the first time I read through all of the notes and did the activities because a lot of the information is logical based on common sense (especially when finding senses and balancing couples). I did like all of the "learn by doing" sections because although there were a lot of them to complete, the more I practiced the easier these concepts became.
	most difficult part of this was applying the imagery of a couple as a hand. Besides that, this section wasn't too complex.
	At first, I had a little difficulty, but after a few did I get this's I feel like I have a better understanding of couples.
	overall, this module was easy, but the couple magnitudes and different angles are a little tricky.
	I liked this module. I felt this did a good job at explaining the material and for the most part I understand couples. I do not understand how the couples moment is determined nor do I understand if a couple is the magnitude of its sum - or just the magnitude of one "member" of the couple.
	I understand how to calculate couples and find it rather simple, but I'm having some trouble with finding when certain forces can be described as a couple. Maybe a few more examples could help.
	I had a hard time figuring out where to calculate the moment from in a couple
	I thought that this module was relatively straight-forward and pretty easy to understand. The only thing that I slightly struggled with was determining the perpendicular distance between the couples instead of between some given point.

Fig. 3 Excerpts from Module 6 My Response Report

### 3.2 DDL features currently under development

#### a. Interactive Exercises Reports

We plan to develop reports that quantify participation in individual interactive exercises for all the modules of the course. While log files are kept for activities in all modules, such data are not useful real-time analysis. Thus far, only in modules 6 and 7 are student activities in the interactive exercises processed for immediate use in the DDL. Figure 4 shows a snapshot of the report providing quantified information on overall class use of interactive exercises in module 6.

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Fig. 4 Screenshot of Module 6 Assignments and Students Report

The instructor will also be able to see a detailed report for each of the interactive exercises, aggregated across all students in the class. Figure 5 shows samples from such a report from module 7.



Fig. 5 Example of a Module 7 Interactive Exercise Report

# b. Quizzes

Quizzes are intended to be graded assessments at the end of each module, with credit potentially awarded depending on the instructor. (Note that the LBD and DIGT tutors are intended to be

used purely for student learning.) In the fall of 2009 only quizzes for modules 6 and 7 were administered online. In the spring of 2010 quizzes at the end of all existing modules will be available online. In Figure 6 we show excerpts from Module 7 Quiz Report.



Fig. 6 Screenshots of Module 7 Quiz Report

### **3.3 Future work on DDL**

We are experimenting with granularity of the feedback provided to the OLI Engineering Statics instructors. If too coarse, the instructor does not know what to adjust, and if too fine, the instructor can potentially be overwhelmed with information to the point of paralysis.

For example, the instructor will be able to look at just the percentage of students in the class who met each of the Learning Objectives for the module (there might typically be several objectives addressed each week, depending on the pace of the class). This would involve aggregating not only across students, but also across multiple activities, sub-portions of which would touch upon common Learning Objectives. If, for example, an objective is not adequately met, then the instructor can look at components of that objective (if it is so divided), or individual interactive exercises that address the objective (or its components) to decide on what to address in class. Or the instructor can request information on learning progress of individual students and offer individualized instruction as appropriate.

So far quiz questions have been tagged with the learning objectives upon which the OLI Statics course has been built. Currently, we are tagging the interactive exercises in all of the modules with the learning objectives. Further adjustments to the granularity will be made thereafter based on the classroom experience of the instructors using the system.

# 4. BLENDING OLI COURSEWARE USING DDL AND RESULTS

Since the Fall of 2007 students at both CMU and Miami University were required to work through the OLI Engineering Statics modules prior to class. Thus, initial exposure and routine learning occurred prior to class, while interactive activities with collaboration between students and instructors occurred in class.

Since Spring of 2009 students were also required to use the "My Response Link" at the end of each OLI module to tell the instructor (i) which concepts/ skills were the most difficult (muddiest points), and (ii) ask questions they would like the instructor to address in class. The instructors reviewed the feedback reports before the lecture, and adjusted the classroom strategy "just in time", choosing the specific topics, concepts, and skills that required extra attention. If many of students cited one particular concept, the whole class period may be devoted to clarifying that concept. If a concept was mentioned by only one or two students, the instructors prepared a response specifically for those students and didn't use class time.

In the Fall of 2009 in addition to "My Response" reports, we monitored the reports on interactive exercises and quizzes for modules 6 and 7; so our choices of topics for lectures were also guided by the results from the LBD and DIGT exercises and online quizzes. In the spring of 2010 quizzes for all modules will be available online, and the results will be viewable by instructors. In the coming semesters LBD and DIGT exercises in other modules will be instrumented, ultimately providing significant data to inform in-class instruction.

In [16] we presented results on studies of usage patterns and learning gains in OLI Engineering Statics in fall 2007 at CMU. As measured by the paper and pencil assessment tests, the learning

gains pre to post were significant. Results on usage were obtained without the DDL, through painstakingly going through log files of individual students at the end of the semester. In that study we found significant levels of usage of individual interactive exercises in modules 1 to 5. In some cases we were able to correlate individuals' usage of the online materials with their performance in other aspects of the class, such as scores on paper and pencil diagnostic quizzes and on class exams. As one example, for one particular module (in which there was significant variation in participation and performance), students who completed a medium or high number of LBD and DIGT tutors performed significantly better on the diagnostic quiz than those who completed few tutors. As a second example, students who completed at least some of the DIGT (self-checking) exercises performed better on the associated class exam than did those who completed none. These findings were interpreted as follows: usage indicative of self-regulation of learning was more correlated with performance than sheer quantity of usage.

We can gain some overall indication of the influence of using progressively more of the OLI online materials, and the use of feedback available then to instructors, from the Statics Concept Inventory scores over recent semesters at Miami University (Table 1).

Table 1. Statics Concept	<b>Inventory scores</b>	at Miami Unive	ersity over pa	ast semesters.

	Mean for comparable schools (no OLI)	S07 (only 5 OLI modules)	F08 16 OLI modules	S09 16 OLI modules	F09 16 OLI modules
SCI score	38%	44%	57%	60%	67%

In the future, having some reports through DDL will allows us to follow students' progress and participation in real time (as oppose to going through log files at the end of the semester).

For example, we can obtain an indication of the numbers of students who worked through modules by looking at submissions of My Response reports. As shown in Table 2, these reports were submitted by 64% to 92% of the 77 students in the class at Miami in the fall of 2009, depending on module.

### Table 2. Submission of My Response Reports (Miami Fall 2009)

module	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
number of students who submitted	69	70	68	69	64	71	64	59	54	66	58	50	62	49	49	55

For modules 6 and 7 (which provide data now to the DDL) we could determine the participation in individual LBD and DIGT exercises, as shown in Table 3.

page in module 7	1		2		3		4		5		6		7	
# of students	<u>s</u>	<u>f</u>	<u>s</u>	f										
(out of 77) who	73	72	71	71	70	60	50	50	52	52	56	55	38	30
s = started	73	73	71	71	67	59	47	47	56	45	53	53	41	41
f = finished	73	73	67	53	63	62					45	28		
each exercise			69	69	51	50					38	20		
on a page					49	27					32	31		

### Table 3. Initiation and Completion of Individual Exercises in Module 7 (Miami Fall 2009)

These results are comparable to those presented earlier [16], in which significant levels of usage of individual interactive exercises in module 5 were found. We hope to have such reports for all the remaining modules by the Fall 2010 semester.

As the course of classroom instruction is increasingly affected by input from the Digital Dashboard for Learning, we will seek to determine whether such input does indeed have marked positive effects on students' learning.

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