Abstract – Motivated by other recent work, we developed, implemented, and began assessment of an Inverted Classroom model for Engineering Statics at UPRM. The model consists of (1) a set of pre-Lecture Modules and Exercises, delivered online; (2) a Lecture that responds to the students’ experience in the pre-Lecture activities, and (3) a Problem-Solving Session after each Lecture. Assessment results from a student survey and an administration of the Concept Assessment Tool for Statics (CATS) were generally positive. The class format, assessment methods, and assessment results are described. A discussion is also provided to indicate how the Inverted model might be implemented for use to unify the delivery of Statics at UPRM.

Index Terms – Inverted classroom, statics, common module instruction, concept inventories, assessment

INTRODUCTION

Founded in 1913, the College of Engineering (CoE) at the University of Puerto Rico-Mayagüez (UPRM) has a 50 year history of delivering accredited, high quality education. It is one of the 15 largest engineering programs in U.S. by enrollment, and has a large proportion (32%) of female students. The UPRM CoE also graduates the greatest number of Hispanic engineers in the U.S. [1]-[2].

The Department of General Engineering has the responsibility to deliver instruction in basic mechanics to all engineering baccalaureate students at UPRM. Each year the Department offers approximately 24 sections of Statics, 16 sections of Dynamics, 12 sections of the Mechanics of Materials I-II sequence, and 3 sections each of combined Statics/Dynamics and combined Mechanics of Materials I/II. With section enrollment capped at 25, these Mechanics courses enroll more than 700 students per semester. One of the authors (C. Papadopoulos) coordinates the Engineering Mechanics Committee that manages the mechanics courses.

Because of the central importance of Statics to the engineering curriculum – on grounds of both its content and methodology [3] – much attention has been paid to developing new approaches to teach Statics, and to evaluate student learning and cognition based on performance in Statics and related topics [4]-[14]. Our work here (also described in [4]) adds to this body of scholarship by developing, to our knowledge, the second effort to implement an Inverted Classroom model to teach engineering Statics, the first being due to Dollár & Steif [5].

Our efforts are also part of a broader, new initiative in the CoE to promote excellence and leadership in engineering education. Motivated by the recent ASEE report “Creating a Culture for Scholarly and Systematic Innovation in Engineering Education” [15], a new Office for Strategic Engineering Education Development (SEED) was created to continuously lead the cycle of Research, Implementation, and Assessment (RIA) throughout the CoE [16]. One of the authors (A. Santiago-Román) is the Director of the SEED Office. Inverted instruction represents an implementation of a best practice, and will generate assessment data and research questions.

THE INVERTED CLASSROOM MODEL

The “Inverted Classroom” is described by Lage et al. as an environment in which “events that have traditionally taken place inside the classroom now take place outside the classroom and vice versa” [17]. Inverted instruction typically provides content and related interactive activities that students are required to complete prior to lecture, and these are usually delivered online. An important principle undergirding Inverted instruction is the incorporation of real time or rapid feedback to both students and instructors so that maximum engagement occurs [5].

We first learned about Inverted instruction from Dollár & Steif [5] who implemented an Inverted class structure for Statics using an online learning environment known as the Open Learning Initiative (OLI) [18]. Impressed with this system, we evaluated it for use in Fall 2009. However, for reasons both practical and philosophical, we elected to create and deliver our own customized modules using PowerPoint slides and interactive features provided by Moodle (the online courseware supported by UPRM) [4], [6], [19].

Our Inverted Statics class consists of three basic components and was delivered to two sections of Statics taught by one of the authors (C. Papadopoulos) in Fall 2009:

1. Pre-Lecture Modules, consisting of PowerPoint slides and companion interactive Exercises (usually online), delivered via Moodle and completed by students prior to Lecture;
2. Lecture, consisting of focused discussion and activities leveraging the prior exposure gained in the pre-lecture Modules and Exercises;
3. Post-Lecture Problem-Solving Session after each Lecture (twice per week), encouraging students to initiate homework and related help-seeking activities.
Because all of the core content is delivered via the Modules prior to Lecture, the Lecture itself contains less “direct lecturing” and more critical discussion and activities that respond to the students’ experiences with the preparatory Modules and Exercises. To foster further student engagement, customized homework assignments were created. This prevented students from copying answers from a prepared solution manual and drove attendance at the Problem-Solving Sessions.

INITIAL ASSESSMENT ACTIVITIES AND OUTCOMES

I. Fall 2009 Survey (Inverted Cohort)

A 42-question survey was given to students in the Inverted class sections at the end of the Fall 2009 Semester. To ensure both anonymity and efficient dissemination and tabulation, an independent staffer in the CoE distributed the survey and collected results via Zoomerang. The staffer provided us with the results identified only by student final grade category: A/B, C, and D/F. Reponses were received from 36 of 63 students who completed the course, including 14/23 A/B, 16/23 C, and 6/17 D/F. We summarize key findings here; a very detailed analysis is provided in [4].

Students generally indicated that the Inverted method caused them to devote more time than for other 3 credit courses. Most (25/36, 70%) indicated that their time was “worth it” or about the right amount, but several (9/36, 25%) responded that it was not “worth it”. Students further indicated that the Inverted method caused them to spread out their effort more regularly (rather than laying off and then cramming). However, they were roughly split as to whether this was primarily motivated by the intrinsic reward of learning, or the pressure that if they did not regularly participate (e.g., Problem-Solving Sessions), they would not be able to complete the course assignments independently.

Students also indicated that the Modules were clear and well designed, and that the Lectures were useful and interactive. Usage statistics further demonstrate that students had a high compliance with completing the required exercises associated with the Modules. However some felt that some material was not covered in Lecture because the instructor assumed it was delivered in the Modules.

Perhaps the strongest endorsement of the Inverted Class was that 29/36 (81%) preferred the Inverted format with Problem-Session and no solution manual over a single other alternative of a traditional lecture-only class with a solution manual and no Problem-Session. Students also expressed a willingness to pay, on average, $2.39 per Problem-Solving Session in the event that fiscal constraints would prevent their continued availability. However, as a general rule, D/F students indicated lower levels of enthusiasm for, perceived usefulness of, and compliance with the Inverted classroom format and associated activities.

II. Concept Assessment Tool for Statics (CATS) Results

The Concept Assessment Tool for Statics (CATS) [7] is a concept inventory that has been statistically validated [10], [11] and has been demonstrated to have a cognitive diagnostic capacity [12], [13]. In the Fall 2009 semester, we administered the CATS to students in both the Inverted sections of Statics and the other “Standard” sections not receiving inverted instruction, once as a pre-test and once as a post-test. The pre-test was taken by 65/76 (36/250) students in the Inverted (Standard) cohort. Pre-test scores for both cohorts were similar to the expected outcome of random guessing, in agreement with Steif & Hansen [11]. The post-test was completed by 46/63 (31/200) students in the Inverted (Standard) cohort, who averaged 8.41/27 (6.52/27). An unpaired t-test indicated that this difference is statistically significant (p = 0.0076). However, the results restricted to only students who took both the pre- and post-tests reveal that 44 (11) students in the Inverted (Standard) cohort completed the post-test with average score 8.70/27 (7.36/27). An unpaired t-test showed that this difference is not statistically significant (p = 0.21).

Clearly, further data must be taken to draw strong conclusions, including greater numbers of students from the Standard cohort to take both the pre- and post-tests. Nevertheless, we interpret our relatively positive findings, coupled with other independent evidence [14], to justify devoting further effort to design and implementation of the Inverted instructional model in our Department.

FUTURE DEPARTMENTAL EFFORTS

Continued delivery and assessment of the Inverted Statics Class is in progress during Spring 2010. At a meeting of the Engineering Mechanics Committee in March 2010, a majority of members expressed their support to unify the teaching of the mechanics courses across all sections, particularly for Statics. The Committee reached a consensus to define Common Modules for Statics and to undertake a plan to cooperatively design, deliver, and manage them. This Common Module approach will be piloted for delivery in Fall 2010 by voluntary participation of Committee members, and is targeted to be uniformly adopted by Fall 2011.

In the development of the Common Modules, the Committee will focus on how to implement interactive tools that require student engagement and provide feedback. The platforms of both our inverted classroom model and that of Dollár & Steif/OLI [5], [18] will be reviewed. An advantage of our model is that it can be readily modified and controlled locally, allowing different members of the Committee to contribute content and exercises. An advantage of the OLI is that its structure for providing flow control and feedback within modules is very highly developed and sophisticated.

CONCLUSIONS

Initial assessment of our Inverted model for Statics is generally positive and justifies further development and use. It and the OLI-based Inverted classroom model will be reviewed by the Engineering Mechanics Committee of the Department of General Engineering for use as platforms to deliver unified, Common Module instruction in Statics.
REFERENCES


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