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Design of Flipped Classroom Model for a Computer-Aided Structural Analysis Design and Experimentation Course

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Abstract

Engineering course redesign with educational pedagogy is gaining widespread acceptance. There is a move from teacher-centered lectures to student-centered active learning strategies that will benefit student learning. It is important that students develop critical thinking and analytical skills that will form the basis of lifelong learning. In this regards many educators have developed project-based learning exercises in engineering and other courses so that the students will learn by doing. Project-based learning motivates the learners and provides "hands-on" and "minds-on" training. A laboratory-based civil engineering course in Computer Aided **Structural Analysis Design and Experimentation** is redesigned using Fink's Taxonomy of significant learning with learning goals and several dimensions from foundational knowledge, application, integration, human dimension, caring and learning how to learn. In this respect, e-Learning plays a critical role in knowledge and skills development as well as course management. Learning Management System Moodle is used as an e-Learning tool for communication with students. The course materials developed include video components of lectures as flipped classes, and electronic clickers to engage students in the classroom, and Moodle LMS as a vehicle for engaging students outside the class through discussion sessions and accessing course materials such as video lectures.

Introduction

The objective of this paper is to demonstrate how an existing course was redesigned to a Flipped classroom model using educational pedagogy of Fink [1] as e-learning is becoming popular. This was implemented in a junior level civil engineering undergraduate classroom at a predominantly undergraduate institution, at a California State University campus. This learning experience was designed, with components webinars for background information (case studies), a design project, hands-on demonstration models, and experimentation on a small instructional shake table and using clickers in the classroom for student response.

Students learning initiatives in earthquake engineering have been pursued by many academics such as Einde [2]. Parallel to these, research is continually working on advancing the state of earthquake engineering knowledge and applications through cutting edge research. One such initiative is the research in Linked Column Frame (LCF) system [3] as an alternative to the traditional moment frame system for lateral resisting frames for earthquake loads. Currently, there is a tremendous demand for bringing civil engineering research results in undergraduate classrooms with active learning pedagogy [4] and to use technology for education [5]. For example, the University of Southern California has a completely online degree in Structural Engineering [5]. Another example is the use of the Flipped classroom model [6]. The current paper addresses the application of the

Flipped classroom model in a Structural Engineering laboratory course at the junior undergraduate level.

The Course

The course selected to introduce the Flipped classroom model concepts was a junior level civil engineering laboratory course, CE382 "Computer Aided Structural Analysis, Design and Experimentation Laboratory." The prerequisites for the course are i) Strength of Materials Laboratory and ii) Introduction to Structural Design. The catalog description for the course includes "Computer Aided Structural Analysis and Design using structural simulation software as encountered in practice. Computer-aided structural experimentation and comparison of structural experimentation with structural analysis software." This is a 3-hour laboratory course that includes the use of software and experimentation. The software used for structural analysis and design is SAP 2000 [7] simulation program.

The student learning outcomes for the course are knowledge of engineering principles (abet a), knowledge of current design specifications, and knowledge of computer-aided structural analysis and design. In addition, skills outcomes for the course are the ability to identify, formulate, and solve structural engineering problems (abet e), ability to plan and design a system, component or process that meets desired needs (abet c), ability to use techniques, skills, and modern engineering tools necessary for engineering practice, including computer tools and information technology (abet k), and the ability to design and conduct experiments as well as to analyze and interpret data (abet b).

The course topics traditionally include computer-aided structural analysis of trusses, 2D-frames for gravity and lateral loads and load combinations, computer-aided structural design of 2D-frames, setting up of an experiment on a small shake table and dynamic experimentation, computer-aided structural dynamic analysis with time history, and verification of computer-aided analysis results with experimentation.

This course has been traditionally taught with a roof truss example and a moment frame example. This analysis includes gravity and lateral loads. Also, the design includes a verification example of an experiment on a shake table for a single degree one-bay-one-story metal frame. As part of a course redesign with active learning with the Flipped Classroom model, using the Fink Taxonomy [1]. Table 1 describes Goals, Criteria for Learning Goals, and Standards for Fink Taxonomy [1].

Table 1: Significant Learning for Fink's Taxonomy

Learning Goals	Fink's Dimension	Criteria
Students will master basic structural engineering concepts	Foundation	1. Students should be able to demonstrate knowledge in previous classes. 2. Students should be able to apply structural design principles for steel design. 3. Students should be able to demonstrate key concepts in structural laboratory materials testing learned in previous classes.
Students will be able to demonstrate concepts of earthquake response to structures	Application	1. Students should be able to perform a laboratory experiment of a model structure to demonstrate the phenomena of resonance. 2. Students should be able to perform a laboratory experiment of a model structure to demonstrate the structural response to earthquakes. 3. Students should be able to perform computer-aided structural simulations of a model structure to earthquakes.
Students will build an appreciation of the societal impact of structural engineering decisions	Caring	1. Students will understand professional and ethical responsibility

For each criterion, there is a standard to determine how well the criteria are met.
For example for the Caring criteria 1, the standard is the hypothesis " Can identify an ethical situation in structural engineering decisions, and analyze it using applicable codes of ethics."

Activities for the course is centered on a Collaborative Project-Based Learning (CPBL) with various possible structural systems to resist earthquake forces for buildings, such as that shown in Figure 1.

Figure 1: Examples of an Earthquake-Resistant Systems

Tools for the course are:

i) Online Learning Management System (LMS)
Model – allows communication with students, collecting homework, grades, minute paper, muddiest point, online learning communities (discussion groups).

ii) Webinars for background information (Case Study)
They were designed incorporating Quizzes for testing students' comprehension.

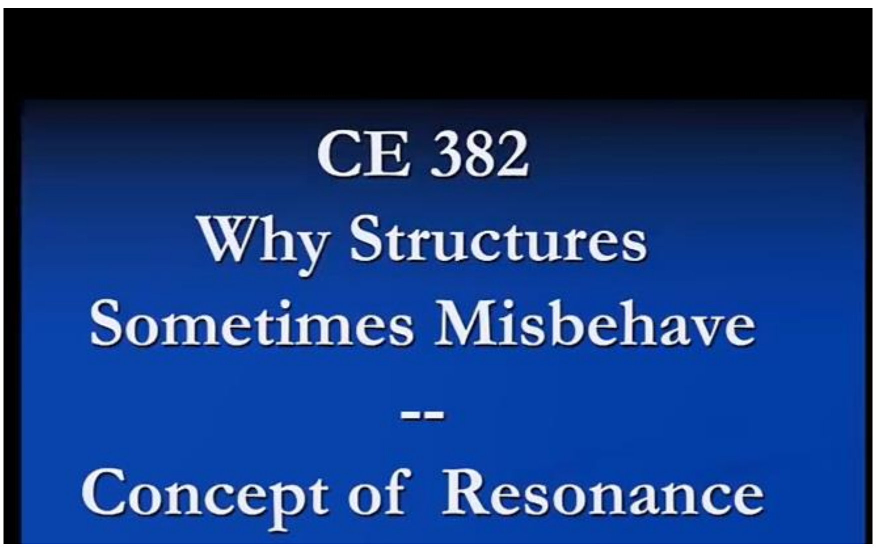

Figure 2: An Example of a Webinar on Concept of Resonance on Moodle

iii) PowerPoint Slides:
One of the PowerPoint Slides was on Social Impact of Structural Engineering decisions.

iv) Use of e-clickers to keep students engaged and also as a tool to take attendance.

Structural models for use:

Scaled down structural models are to be tested on a small instructional shake table to demonstrate the natural period of the structure, the concept of resonance due to shaking table excitation with different frequencies, and acceleration amplification of story floors due to shaking table excitation of sample scaled earthquakes such as scaled-down Northridge Earthquake. Figure 3a, b, c, depict several structural models developed for the class. Figure 4 depicts the SAP2000 computer simulation model of Figure 3a developed for numerical analysis and design. Figure 5 depicts the response displacements and accelerations as expected from SAP 2000 numerical simulation for comparison with experimental results.

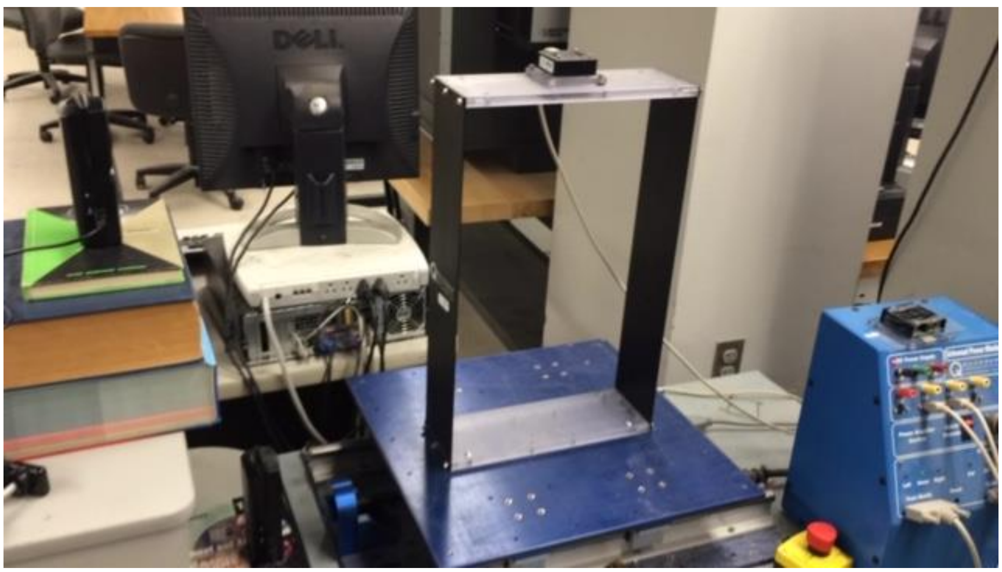

Figure 3a: Scaled Structural Model of a Moment Frame

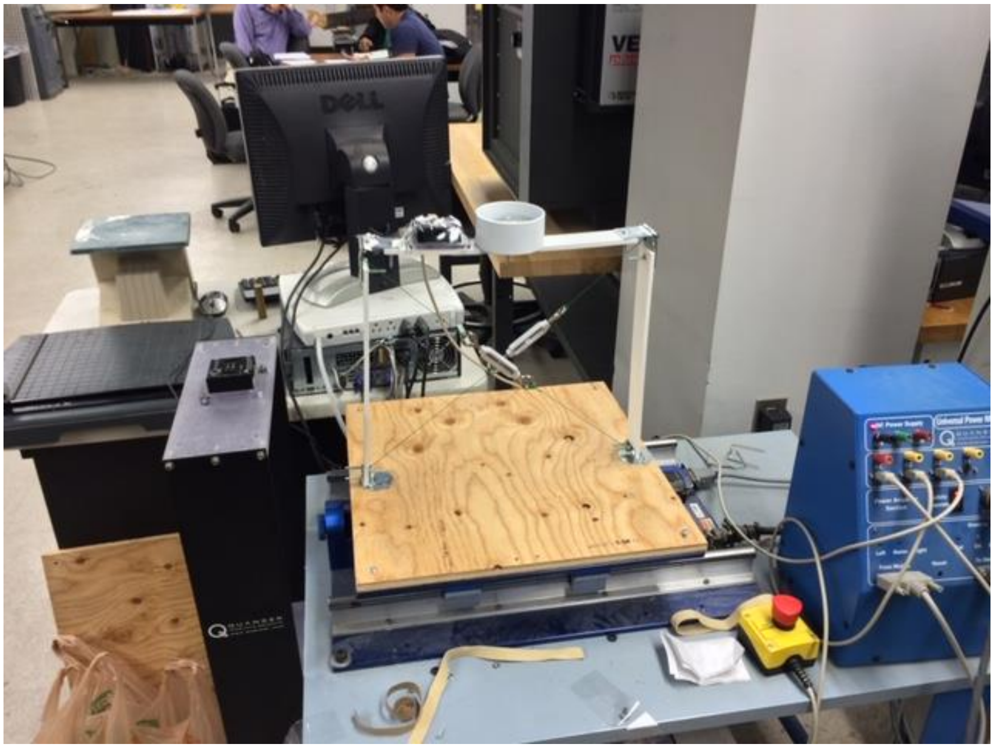

Figure 3b: Scaled Structural Model of a Braced Frame

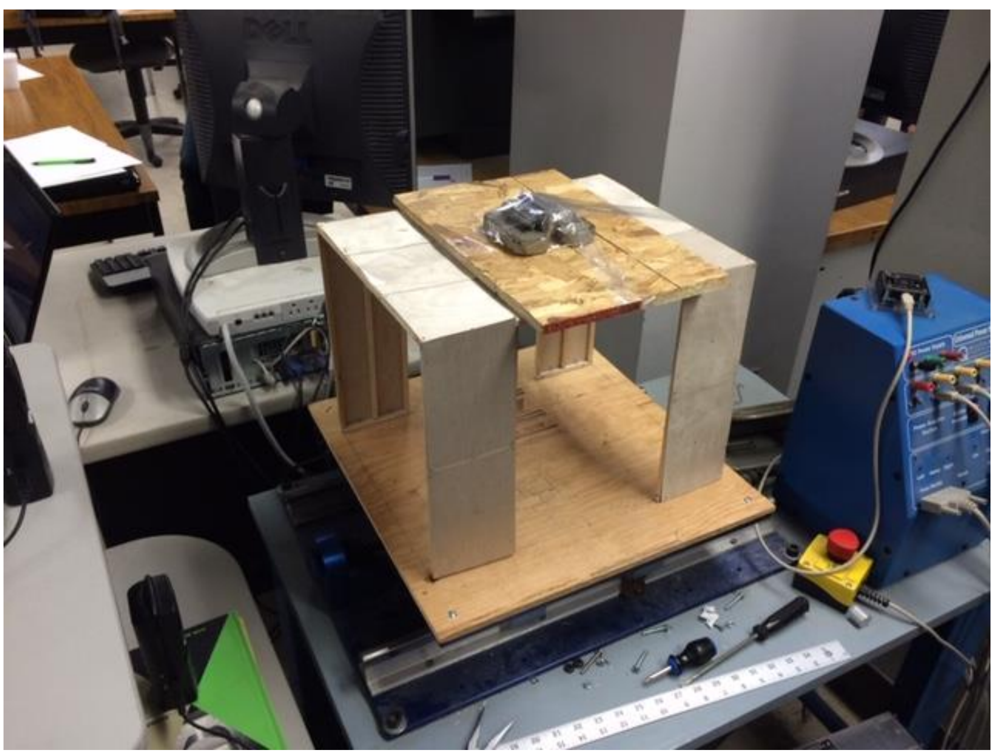

Figure 3a: Scaled Structural Model of a Shear Wall Building

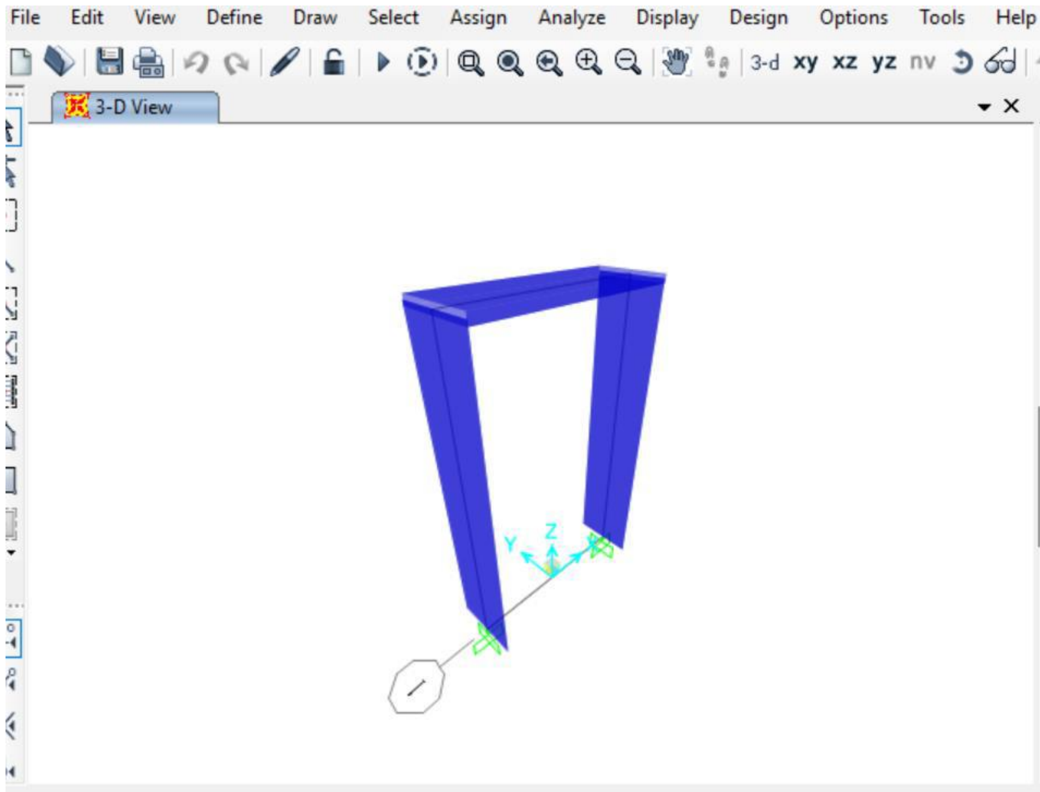

Figure 4: SAP2000 Analytical Model

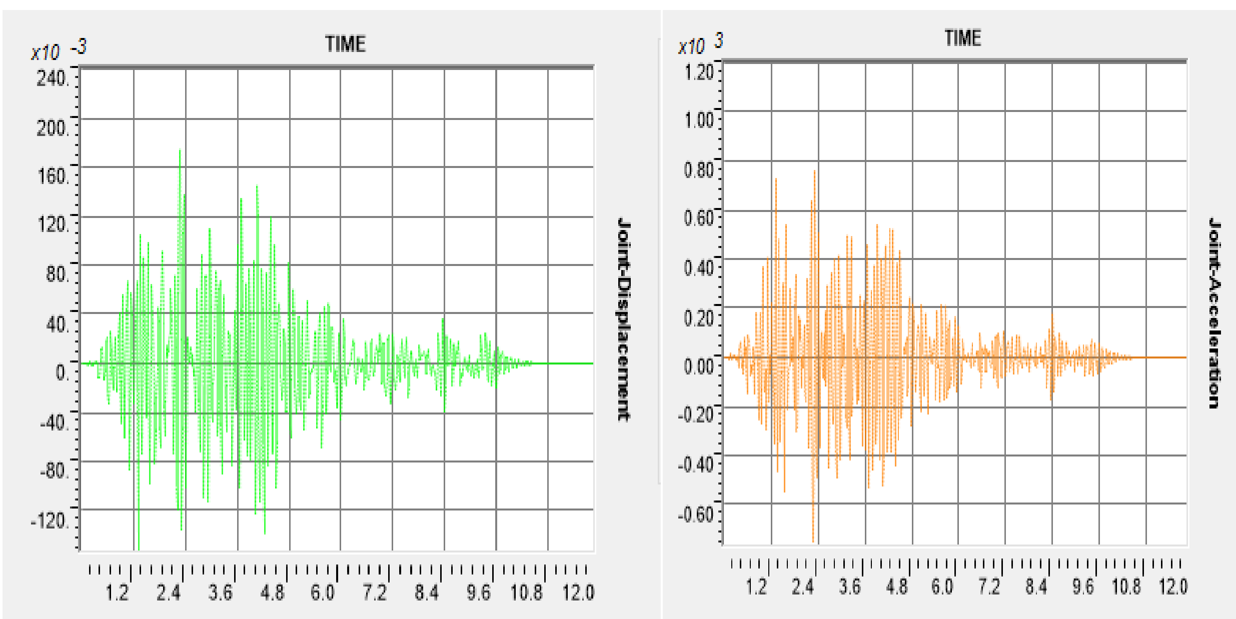

Figure 5: SAP2000 Response Displacement and Acceleration Records of Model in Figure 4 (units inches and seconds)

Conclusions

The paper presents the Design of the Flipped Classroom Model for a Computer Aided Structural Analysis Design and Experimentation Course using instructional technology, structural models, experimental testing, and verification through analytical structural simulation. The course is designed using a collaborative Project Based Learning Model centered on earthquake resilience which is very appropriate for California.

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