Internalizing the Symbolic World: Using Low-Cost Shake Tables to Convey Earthquake Engineering Concepts to Secondary School Students (K-12 Division: Curriculum Exchange)

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Eric completed his B.S. degree in 2007 and his M.S. degree in 2008 in Structural Engineering from UC San Diego. In 2011, Eric earned his M.B.A. from San Diego State University with a coursework emphasis in finance and a thesis outlining a competitive framework for firms in the transportation industry pursuing Design-Build projects. He is currently pursuing his Ph.D. at UC San Diego in the field of Structural Engineering.

Eric is a licensed P.E. in the state of California and has worked as a bridge engineer for both T.Y. Lin International and Moffatt & Nichol. Eric has been involved in the design or independent check of a number of projects, most notably: Veterans Memorial Bridge (Portland, ME), Port Mann Bridge (Vancouver, British Columbia), and Milliken Avenue Separation (Ontario, CA).

Dr. Yael Van Den Einde, University of California, San Diego

Van Den Einde is a Teaching Professor at UCSD. She teaches core undergraduate courses in Structural Engineering, is the chair of the ABET committee responsible for the continuous curricular improvement process, incorporates education innovations into courses (Peer Instruction, Project-based learning), is responsible for TA training (preparing next generation faculty), serves as faculty advisor to student organizations, hears cases of academic misconduct as a member of the Academic Integrity Review Board, and is committed to fostering a supportive environment for diverse students at UCSD by serving on the faculty advisory board for the IDEA Student Center. Her research is focused on engagement strategies for large classrooms and the development of K-16 curriculum in earthquake engineering.

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Target Grade Level: Grades 9-12.

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Background

In order to recruit more students into engineering majors and ultimately improve college level academic performance, students must be exposed to and excited about engineering from an early age. However, demonstrating challenging concepts that require complex mathematics, which most students have yet to be exposed to, is difficult. This task is exacerbated if students feel lost in the concepts and become disengaged. Several earthquake engineering modules capitalizing on the use of a low-cost, commercially available instructional shake table (developed by the Network for Earthquake Engineering Simulation; see Figure 1) have been developed to address these issues. In each module concepts are broken down to their fundamental levels and presented to students through a combination of lectures, videos, peer instruction, in-class demonstrations, and construction based projects to increase student comprehension. The modules goals are to build the students' knowledge base through interactive activities, generate excitement about engineering, and develop a physical intuition about engineering concepts.

Earthquake Engineering Modules (Abbreviated)

Two earthquake engineering modules are briefly described here. A third module, a comprehensive capstone design project, is described in detail in the next section.

- *Soil Liquefaction and Foundations*: Introduces students to geotechnical considerations in seismic regions and methods to mitigate for poor soil conditions. This demonstration illustrates the potential effects of liquefaction on structures (see Figure 2). Structures with various foundations are tested to show differences in performance.
- *Shear Wall Design*: Students observe poor performance of a basic timber frame structure subject to a seismic event and the improved performance when shear walls are included (see Figure 3). Students then compete in an in-class design challenge to build a two-story, two-bay balsa structure capable of surviving a strong seismic event.

Capstone Seismic Design Project

Students are tasked with designing, fabricating, and testing a balsa wood braced frame to ensure structural adequacy against a scaled earthquake ground motion (see Figure 4). In-class activities begin with instructor presentations to introduce and explain the relevant engineering concepts. Students then work through numeric problems to ensure conceptual understanding and complete a tutorial which progresses through a trial frame design. After the tutorial, students begin their original design and iterate between calculating structural loads and updating their structural design until they converge to a completed individual design. The class is then divided into teams where each team is directed to generate a final "group" design of the structure. These final "group" structures are fabricated by the students and tested using the instructional shake table. Before testing, students submit a group report justifying their design choices. After

testing, groups report on their structures performance and present their post-collapse findings to the class through an oral presentation. Over the course of the module, students (a) develop structural models using free computer software, (b) calculate structure dependent seismic loads, (c) iterate their designs to ensure sufficient structural capacity, (d) construct and test a physical model, and (e) optimize a performance index.

The capstone modules total duration is twenty in-class hours and can be executed at a unit cost of $2 per student (this does not include the cost of the shake table). The module contains vetted handouts and supplements (a teacher's guide, all necessary student handouts, PowerPoint presentations for instructor use, design examples, software tutorials, fabrication tips, grading rubrics, and videos of an engineer presenting the module) that permit an instructor who may not have an engineering background to properly present the module. The videos are especially useful: enabling would-be instructors to see how the module is intended to be presented and hear responses to likely student questions. The module has been field tested at two high schools; a previous instructor provided the following comments: "The rigor of the design and build process resembles that which students can expect to see in college projects. The PowerPoint presentations and student handouts are of excellent quality and packed in such a way as to ensure comprehension of the material." (Fischer, personal communication, 2014) More information regarding this module can be found in Kjolsing and Van Den Einde (2014).

Module Acquisition

The capstone seismic design module can be obtained at no cost by contacting either author. Interest in obtaining documentation for other curriculum described should be directed to the second author.

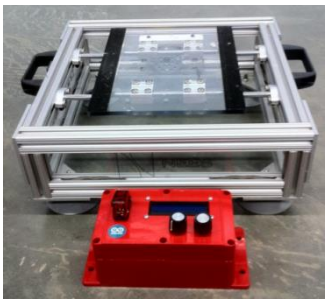

Figure 1. NEES Instructional Shake Table

Figure 2. Soil Liquefaction Demonstration: Structure Before (Left) and After (Right) Shaking

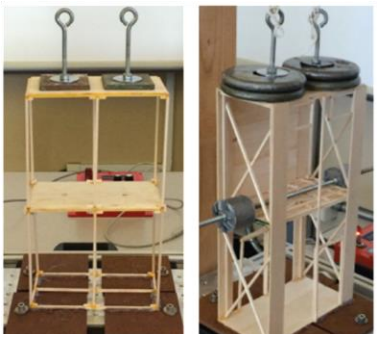

Figure 3. Shear Wall Design Demonstration: Structure with (Right) and without (Left) Shear Walls

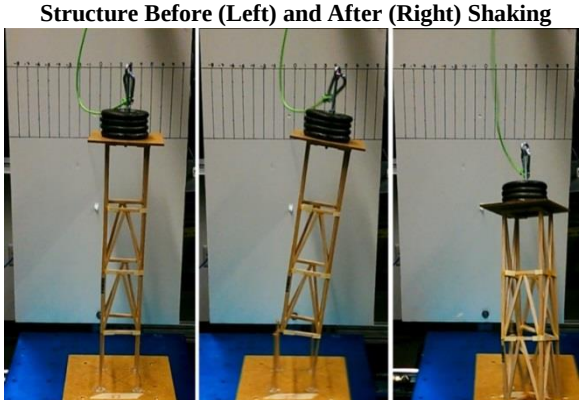

Figure 4. Seismic Testing of Balsa Braced Frame

[1] Kjolsing, E., and Van Den Einde, L. (2014). Development of a Seismic Design Module for National Deployment in Project Lead the Way High Schools. *Journal of Professional Issues in Engineering Education & Practice.*