DEVELOPMENT OF EARTHQUAKE ENGINEERING CURRICULUM FOR HIGH SCHOOL STUDENTS USING LOW-COST SHAKE TABLES

Lelli Van Den Einde
Overview

- Introduction
- NEES Low Cost Instructional Shake Table
- NEES Shake Table Working Group
- Pilot Implementation with Project Lead The Way
  - Example Curriculum
- Assessments & Results
- Recommendations & Conclusions
- Acknowledgements
Introduction

• Engineering is critical to developing a community and workforce that understands the technical nature of the manmade world

• There has been a recent national push (NAE 2010) to improve K-12 STEM education, and specifically integrate informal engineering modules into K-12

• NEES is a leader in Education, Outreach and Training (EOT) for the earthquake engineering community
  o NEES community has developed curricula and outreach activities and has shared learning resources, objects, and modules through the NEESacademy
  o NEES has developed a low-cost instructional table for education & outreach
Introduction

• A primary part of students being able to construct knowledge and increase their interest in engineering is by engaging them in authentic scientific and engineering activities
  o Experiential learning is the process through which knowledge is developed via the use of engaging, hands-on activities and experiences that draw on prior understanding in order to form new connections
  o Experiential tools such as instructional shake tables can teach students about fundamental physics principles and can stimulate their interest in STEM careers.
  o Project Based Learning (PBL) allows students to grow through assisted problem solving activities that center on complex problems for which a variety of solutions exist
Project Objectives

• To develop **experiential and project-based** earthquake engineering learning activities for high school students using the NEES low-cost instructional shake table.

  o Expose and recruit students into engineering
  o Broadly disseminate curriculum through Project Lead The Way (PLTW)
  o Develop packages consisting of lectures, demonstrations, activities, lists of materials, teacher/student documentation, and assessment tools
  o Develop plan for mass production of instructional shake table, including hardware/components for the experiments/demos
NEES Instructional Shake Table

- Prototype of motion controlled table was designed and built by Purdue EPICS students
- Control box and shake table can be used to manually specify harmonic motion (sinusoidal)
- Software can run additional modes of operation, gather sensor data and plot it to screen
  - Sinusoidal
  - Earthquake
  - Make Your Own Earthquake (MYOE)
  - Impulse
  - Shaker
## NEES Instructional Shake Table

### Specifications

<table>
<thead>
<tr>
<th>Specification</th>
<th>NEES-EPICS</th>
<th>Quanser (or MTS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight</td>
<td>11 pounds (control 1 lbs, table 10 lbs)</td>
<td>&gt; 25 pounds</td>
</tr>
<tr>
<td>Frequency</td>
<td>0.5 Hz min – 10 Hz max</td>
<td>0.5 Hz to 15 Hz</td>
</tr>
<tr>
<td>Amplitude</td>
<td>5 cm p-p</td>
<td>7 cm p-p</td>
</tr>
<tr>
<td>Operating Modes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sinusoidal position</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Sinusoidal velocity</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Earthquake</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Make your own Earthquake</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Impulse</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Shaker motor control</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Open source code</td>
<td>Yes</td>
<td>Proprietary</td>
</tr>
<tr>
<td>Sensor input channels</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Static Load (vertical)</td>
<td>4.5 Kg</td>
<td>15 Kg</td>
</tr>
<tr>
<td>Dynamic Load (horizontal)</td>
<td>+/- 2 g</td>
<td>+/- 2.5 g</td>
</tr>
<tr>
<td>Table dimensions</td>
<td>36 x36 cm</td>
<td>45.7 x 45.7 cm</td>
</tr>
<tr>
<td>Control box Dimensions</td>
<td>74x158x90mm</td>
<td>450 x 450 x 500 mm</td>
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**NEES** Instructional Shake Table

- Specifications

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NEES Shake Table Working Group (STWG)

- NEES Education, Outreach and Training (EOT) Committee initiated an effort to develop, harden and broadly disseminate earthquake engineering curriculum
- Established a NEES Shake Table Working Group (STWG) made up of EOT representatives from the NEES community

<table>
<thead>
<tr>
<th>University</th>
<th>Participant</th>
</tr>
</thead>
<tbody>
<tr>
<td>UCSD</td>
<td>Lelli Van Den Einde, Lead</td>
</tr>
<tr>
<td>UMN</td>
<td>Cathy French</td>
</tr>
<tr>
<td>UCB</td>
<td>Heidi Tremayne</td>
</tr>
<tr>
<td>UNR</td>
<td>Kelly Doyle</td>
</tr>
<tr>
<td>OSU</td>
<td>Alicia Lyman Holt</td>
</tr>
<tr>
<td>Howard University</td>
<td>Claudia Marin</td>
</tr>
<tr>
<td>NEEScomm</td>
<td>Thalia Anagnos, Sean Brophy, Keith Adams</td>
</tr>
</tbody>
</table>
NEES Shake Table Working Group (STWG)

- NEES STWG was tasked to inventory existing curriculum across the country and select a handful of exercises and projects based on a rigorous rubric:
  - Two undergraduate students at UC San Diego
  - Assessed whether the activities identified were sufficiently developed with enough documentation and learning outcomes to be easily scalable.
- Vetted selections with Project Lead the Way (PLTW) teachers to select modules that were aligned with existing PLTW curriculum.
Pilot Implementation with PLTW

- Non profit organization: leading provider of rigorous and innovative STEM education curricula [http://www.pltw.org/](http://www.pltw.org/)
  - Develop hands-on, project-based courses for elementary, middle and high schools around the U.S.
  - Courses have been integrated in >4,700 schools across the country.
  - Train more than 3,000 teachers each year to instruct their curriculum.
  - California teachers expressed interest in bringing seismic concepts into their courses

- Collaborated with local PLTW organization to ensure curriculum was aligned with state standards and appropriate for high school implementation
Targeted two PLTW courses to pilot

- **Principles of Engineering (POE):**
  - Mira Mesa High School:
    - Teacher: Eric Fischer
    - 32 Students
  - Scripps Ranch High School:
    - Teacher: Mena Abdo
    - 35 Students

- **Civil Engineering and Architecture (CEA)**
  - Stanley E. Foster Construction Tech Academy at Kearny High School
    - Teacher: Timothy Bingham
    - 14 Students (underrepresented minorities)
Example Curriculum
POE Course

- Truss Bridge Project
  - Analyze truss, Optimize design, Construct out of prefab pieces
  - Predict failure mode, Test to failure (typically buckling of compression member).
Example Curriculum
POE Course

- New Capstone Design Project (Water Tower)
  - Conceptual Design
  - Analyze in RISA
  - Optimize using provided spreadsheet
  - Fabricate water tower
  - Test structure
  - Paper/Presentation deliverable
Example Curriculum
POE Course
Example Curriculum
CEA Course

• Lectures: Vibrations, Seismic Design principles, Liquefaction, Base Isolation, and Seismic Provisions for their Capstone Project

• Demonstrations
  ○ Masses on Rods, liquefaction

• Projects (integrated with Keystone Library Capstone Project)
  ○ Timber Design Project
  ○ Shear Wall Design
  ○ Design of pile foundation and/or base isolator
Example Curriculum
CEA Course

Masses with Rods
Example Curriculum CEA Course

Liquefaction of Structure  
Liquefaction with Piles
Example Curriculum
CEA Course: Timber Project

Shear Walls Work
Finding Resonance
Example Curriculum
CEA Course (Capstone)

Shear Wall Design
Pile/Base Isolation Design

P-M Diagram

10th U.S. National Conference on Earthquake Engineering
https://nees.org/resources/3832
Assessment & Results

• Surveys were conducted for all classes/activities.
• Preliminary results show that students understood and retained the main concepts that were taught.
• Many felt the tutorial documentation could be improved but liked the hands-on nature of the projects.
  o “I think that the directions in the papers given to us should be re-written because they were very confusing.”
  o “I liked the activities and hands-on learning. It helped me understand the material a lot better through visual displays.”
  o “I liked testing out structures on the shake table.”
  o “I did not like that we had very little time to do anything. I wish we would have been given more time to complete these activities. I feel like that would have helped me understand the material better.”
If I increase the mass of a system (and hold all else constant), what happens to the period?

Answered: 64  Skipped: 0

- Goes up: 64%
- No change: 7%
- Goes down: 29%
The Seismic Design handout was helpful.

Answered: 64  Skipped: 0

- Strongly agree
- Agree
- Neutral
- Disagree
- Strongly disagree

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
The lecture material was difficult for me to understand.

Answered: 64  Skipped: 0

- Strongly agree
- Agree
- Neutral
- Disagree
- Strongly disagree
I enjoyed seeing videos and photos of damage from real earthquake or experiments conducted on shake tables.

The lecture material was too difficult to follow.

The lectures maintained my interest throughout.

Adding the seismic design components (design of a shear wall, pile, and base isolator) into the capstone library project is a good addition to the project.

The tutorial that led me through the design of a shear wall for the seismic portion of the capstone library project was easy to follow.

The tutorial that led me through the design of a base isolator for the seismic portion of the capstone library project was easy to follow.

The tutorial that led me through the design of a pile foundation for the seismic portion of the capstone library project was easy to follow.

The tutorials for the shear wall, pile foundation, and base isolator were too long.

I understood the concepts required to design the shear wall, pile foundation, and base isolator.

The tutorial that led me through the design of a pile foundation for the seismic portion of the capstone library project was easy to follow.

I was able to apply knowledge gained from the seismic design lectures (shear wall, cross bracing, stiffness, vibrations...) to the balsa wood project.

Adding the seismic design components (design of a shear wall, pile, and base isolator) into the capstone library project is a good addition to the project.

The tutorial that led me through the design of a base isolator for the seismic portion of the capstone library project was easy to follow.

The tutorial that led me through the design of a pile foundation for the seismic portion of the capstone library project was easy to follow.

The tutorial that led me through the design of a shear wall for the seismic portion of the capstone library project was easy to follow.

I was able to apply knowledge gained from the seismic design lectures (shear wall, cross bracing, stiffness, vibrations...) to the balsa wood project.

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The tutorial that led me through the design of a shear wall for the seismic portion of the capstone library project was easy to follow.

Adding the seismic design components (design of a shear wall, pile, and base isolator) into the capstone library project is a good addition to the project.

The lecture material was too difficult to follow.

The lectures maintained my interest throughout.

I enjoyed using the small table-top shake table for these activities.

The shake table activities made difficult concepts (e.g. force, acceleration, motion and modeling) easier to understand.

The shake table activities engaged me to ask scientific questions.

The shake table activities helped me become a better problem solver.

My knowledge and interest in science, technology, engineering and math concepts increased as a result of hands on activities with shake tables.
## Top two take home messages for Overview Video

<table>
<thead>
<tr>
<th>Course #</th>
<th>Top Response</th>
<th>% Responses</th>
<th>2nd Response</th>
<th>% Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>SE 182</td>
<td>Cast-in place foundation (coded as CF)</td>
<td>40%</td>
<td>Construction of Beams, Columns and Shear Walls (coded as CO)</td>
<td>36.7%</td>
</tr>
<tr>
<td>SE 151b</td>
<td>Construction of Beams, Columns and Shear Walls (coded as CO)</td>
<td>14.4%</td>
<td>Rebar/rebar cage (coded as R)</td>
<td>14.4%</td>
</tr>
<tr>
<td>COSMOS</td>
<td>Construction of Beams, Columns and Shear Walls (coded as CO)</td>
<td>52.2%</td>
<td>Importance of Shake Tables (coded as ST)</td>
<td>26.1%</td>
</tr>
<tr>
<td>SE 103</td>
<td>Cast-in place construction (coded as CP)</td>
<td>30.7%</td>
<td>Concrete pouring; concrete construction (coded as CC)</td>
<td>14%</td>
</tr>
</tbody>
</table>
**Dissemination through**

![PLTW Logo]

- **Teacher training**
  - **CEA Training workshop at SDSU: June 15-28**
    - Introduced curriculum and showed shake table demonstrations
    - “I liked it because it is a somewhat interactive activity where I feel that the CEA curriculum is lacking those compared to the only other PLTW Pathway to Engineering I have been exposed to. One of my goals is to find creative ways to integrate hands on activities to existing learning. Where this does not augment existing lessons, it is a nice addition.”
  - **POE Training workshop at SDSU: July 6-19**
    - Tomorrow will demonstrate truss bridge project and water tower capstone project.
Conclusions & Future Work

• Presentation described ongoing effort to take existing earthquake engineering curriculum and modify, enhance and harden it so that it can be broadly disseminated into K-12.
• Curriculum designed to use the low cost shaking table developed by NEES
• Pilot study with Project Lead The Way (PLTW) provided formative and summative assessments for the development of the curriculum and documentation.
• Once finalized, the documentation will be made available as alternative resources for POE and CEA teachers regionally, which will serve as a pathway for integration into national PLTW curriculum for broader adoption.
• Modules will also be made available through the NEESAcademy
• Currently working on improvements to the instructional shake table and possibilities for mass production.
Acknowledgements

• This work was funded by the National Science Foundation (NSF) through the George E. Brown, Jr. Network for Earthquake Engineering Simulation program (CMMI-0927178).
• Duane Crum and Bruce Westermo from PLTW California for their guidance and participation on this project
• PLTW instructors Mena Abdo, Timothy Bingham, Eric Fisher for their enthusiasm and willingness to integrate this into their courses
• UCSD students Eric Kjolsing, Alex Timmerman, Anthony Adams, Mary Kleping, Jose Gomez and Mark Case for their contributions to the documentation and countless hours assembling demo materials.
• Members of the NEES STWG: Cathy French, Thalia Anagnos, Sean Brophy, Keith Adams, Claudia Marin, Alicia Lymon-Holt, Kelly Doyle, and Heidi Tremayne.
References

- http://quanser.blogspot.com/2013/02/how-quanser-shake-tables-are-shaking-up.html
- Image courtesy of Sean Brophy, Purdue University.
Any Questions?