Resonance Resonates: Predict, Experience, Reflect

Abstract
An effective approach for implementing an interactive lecture demonstration involves three stages: predict, experience, and reflect.

Predict

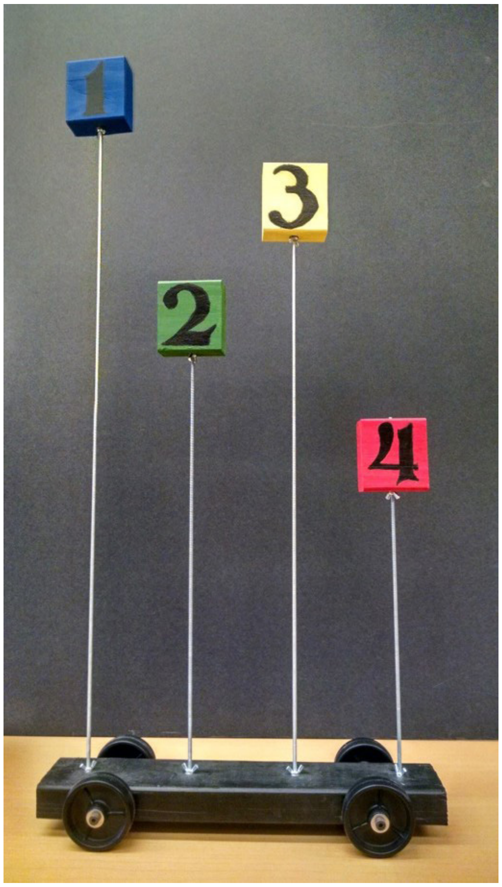
It is shown that students who just passively observe a demonstration do not have a better understanding of the subject than students who do not observe the demonstration at all. However, involving students by asking them to predict the outcome of the presentation yields a better understanding. With this concept in mind, students were asked to predict which “building” would sway the most in an “earthquake”.

The word “building” is in quotes because it is represented by a wooden block on top of a threaded rod. Four blocks of the same size are each attached on top of 4 threaded rods of different heights. This teaching tool is called the **Building Oscillation Seismic Simulation (BOSS)** model, a pedagogical physical demonstration developed by the American Geophysical Union and revised by the Incorporated Research Institutions for Seismology (IRIS) consortium. Since the blocks are all the same weight, the only difference between the four “buildings” is the stiffness, as represented by the heights. All four “buildings” are placed on a two-by-four, which is mounted on a set of wheels.

Students are asked to predict which buildings will sway the most in an “earthquake”, where the earthquake is simulated by the instructor by oscillating the two-by-four base on wheels. The prediction is done by online polling, where students can observe the class results.

With the above slide projecting on the screen, the instructor then shakes the base with a frequency to excite Building 4 (or 3 or 2), which no one selected. The response of the students is literally an audible ‘gasp’ as students express their surprise at the outcome. Shaking the model to excite the frequency of Building 4 is the most dramatic, as it is the shortest building and most students predicted that the tallest building would move the most. The literature shows that learning by being surprised (disconfirmation) is very effective, as such ‘discrepant events’ highlight a mismatch between students’ observations and their prior expectations, and therefore generate interest. To further the demonstration, the instructor shakes the base to excite Buildings 1, 2, and 3, one at a time. As one student put it in the class evaluations, the demonstration was a form of “magic”: “I will never forget the idea of resonance in skyscrapers” because of the wonderful demo” It was amazing watching different blocks move with different frequencies” (seemed like magic!).”

With their attention and curiosity captured, one can then present the equation and physics behind the “magic”.The slide shown below follows the interactive demonstration with the relevant equation. It can thus be explained that ‘resonance’ happens when the natural period of vibration of the building, which is calculated with the equation shown, matches the frequency of ground shaking. The next step is for them to experience resonance on their own.



The Building Oscillation Seismic Simulation (BOSS) model.

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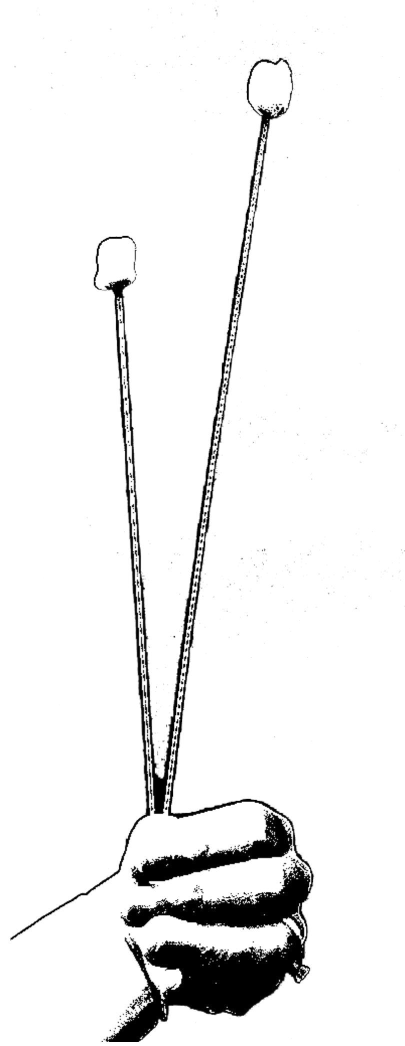
Experience

The course in which this interactive demonstration happens enrolls on the order of 150 students. All of these students can easily experience resonance in their seats (i.e., there is no need to go to a lab) with two pieces of mini marshmallows and two pieces of spaghetti. As shown below, the marshmallows are placed on top of the spaghetti, and the spaghetti are held in the hands with two different heights. The student then shakes his/her hand until it resonates with one spaghetti/marshmallow "building". Then the hands shake at a different frequency until the other spaghetti/marshmallow "building" resonates.



Reflect

In the reflection step, students are presented with a prompt that asks them to apply their understanding in a novel context. Opportunities for reflection help students apply newly-gained knowledge and consolidate their understanding.

In the reflect phase of the interactive demonstration a case study is presented: the 1985 Mexico City earthquake. This slide used in the class, which asks students to reflect on why most buildings that collapsed during the Mexico City earthquake were between 5 and 15 stories. Once again, online polling is used but this time as an open-ended question instead of multiple choice.

The example of 2015 responses is presented in Figure 7 (2016 responses are similar). It is seen in Figure 7 that most students appear to have connected the interactive demonstrations of resonance to a real-world application. They understood that the ground motion period of the Mexico City earthquake was similar to the natural period of vibration of the 5 to 15 story buildings.

Consider that the large majority of the students responding are not engineering students; and consider the anxieties that are partially demonstrated in Figure1. In less than half-hour these students were able to understand resonance in tall buildings.

Learning Outcomes
We adapted the Student Assessment of Their Learning Gains (SALG) survey [14] in order to measure the students' self-reported gains in their skills, understanding of the course content, attitudes towards engineering, as well as gains due to various course components (e.g. assigned readings, lectures, hands-on activities). Partial results of this survey are presented in Figures 8 and 9, which are for 2016. These results are slightly improved from 2015 (where n = 65).

In 2016, 100% of the students (n = 21) reported great, good, or moderate learning gains due to the lecture demonstrations. Furthermore, a large majority of students reported great, good, or moderate learning gains from the hands-on activities (95%), interacting with peers in class (91%), polling questions (81%), and participating in group work (72%). In addition, when reporting on their attitudes towards engineering, 100% of students (N=21) reported good, great or moderate gains in seeing engineering as a creative profession, enthusiasm for the subject, interest in discussing the subject area with friends or family, and in possessing an aesthetic and technical appreciation for bridges, towers, shells, and other structures. These results serve to highlight the efficacy of the interactive teaching methods adopted in this project towards improving student learning outcomes as well as attitudes towards engineering. Further details about our evaluation methods and results can be found in the ASEE 2016 conference paper entitled ' Enhancing Student Cognition and Affect through the Creative Art of Structural and Civil Engineering ' [15].

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