Pre-class exposure to interactive simulations increases efficacy

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Pre-class exposure to interactive simulations increases efficacy

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Interactive simulations are powerful learning tools. However, students often miss the point of an interactive simulation if they see it for the first time in class. A different approach is to use unscripted activities that provide individual engagement with the simulation before class. Pre-class learning activities were created for the "Descriptive Acoustics" class at Brigham Young University that use interactive simulations available on the internet. Provided with basic instructions, the students explore the simulation and write a description of their experience using terminology from the corresponding textbook chapter. Exploration followed by writing, even if incorrect, has increased the level of student understanding and provides a natural way to have students participate in class as they describe their experiences. The pre-class exposure to the interactive simulations also increases the efficacy of using the simulations during class, as each student is familiar with the interface and thus can better follow the in-class demonstration. Interactive simulations are a powerful active-learning tool for the current generation of students but only if they have had personal experience with the simulation prior to seeing it in class.

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1. INTRODUCTION

Interactive simulations are great teaching tools because they provide students the opportunity to engage with the physical phenomena. By moving sliders and turning knobs, students can visualize how their changes affect the simulation. (See for example, paper by Dan Russell[1] and others from this special session.) Today's students are well prepared to learn from interactive simulations if given adequate opportunity to experience them more than once.

Interactive simulations are often used in the same manner as a physical classroom demonstration in which the professor explains what is going on—changing the settings to illustrate different physical principles. In general, if students first see an interactive simulation during class, they rarely understand the concepts being presented because they are trying to figure out what is going on. When the professor changes something about the simulation, students can rarely follow the movement of the cursor and struggle to keep track of what change produced what effect. Thus, the impact of interactive simulations is decreased if students are expected to comprehend the meaning of the simulation when they are first exposed to it.

To increase the efficacy of interactive simulations, pre-class activities are recommended in which students explore the simulations personally prior to the class discussion. This paper details how pre-class activities have been incorporated in a general education acoustics class. After a brief description of the class, details about implementing the pre-class activities are presented. Benefits of pre-class exposure are then discussed, and an example of the pre-class activities is included in the appendix.

2. DESCRIPTIVE ACOUSTICS CLASS

Brigham Young University's "Descriptive Acoustics" class will soon celebrate the 50th anniversary of its 1969 debut. The course was created by William (Bill) Strong on the encouragement from faculty in several departments who understood the benefits of providing students an interdisciplinary exposure to the physical principles of acoustics and applications of these principles to many areas. This course provides students the opportunity to view the world around them and their own disciplines from a complementary viewpoint and covers most of the chapters in *Music, Speech, Audio* by Strong and Plitnick.[2] Students from music, music education, sound recording, communications disorders (which includes pre-audiology students), and other disciplines typically find this course expands their understanding of the nature of sound and the underlying similarities between a wide variety of acoustics-related phenomena. Physics and engineering majors interested in acoustics receive an initial exposure to many acoustics topics and builds conceptual understanding that serves as a foundation for more advanced acoustics courses.

Recently changes—centered on student learning objectives/outcomes—have been made to incorporate active-learning principles.[3,4] A description of the course and changes made prior to 2011 are detailed in Ref. [5], and subsequent developments in Ref. [6]. The current course learning objectives are listed in Table 1. The activities, instruction, and assessments should all be designed towards assisting the students in obtaining the learning objectives (Figure 1). Students can be encouraged to take ownership of their learning when they are provided meaningful opportunities in an active-learning environment.[7,8,9,10,11] Creation of an active-learning environment, however, relies on one key principle that often feels beyond the instructor's control—student preparation.[12]

Table 1 Learning objectives (outcomes) for Brigham Young University's "Descriptive Acoustics" class.

Define the basic **terminologies** of acoustics and **identify** physical **principles** involved in common situations.
Solve basic **problems** and **answer** conceptual **questions** related to hearing, speech, audio, listening environments, and musical instruments.
Apply a few key scientific **models** to solving acoustical problems in many areas including hearing, speech and musical instruments.
Write effectively using proper terminology of acoustics and **logically** outlining how acoustics is important in a discipline of their choice.

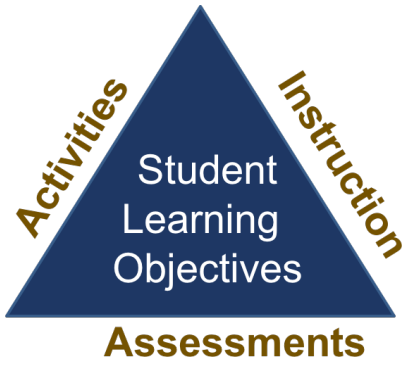

Figure 1 Activities, instruction, and assessment should support the student-centered learning objectives.

To benefit from an active-learning environment, students need to engage with the material before coming to class. The most common attempt to encourage preparation is to assign reading from the textbook;[13] students rarely make time to read the book before coming to class. Reading quizzes are often employed to try to get students to read before class; reading quizzes must be carefully crafted to avoid common pitfalls. Most students learned in junior high that the most important information (i.e., the answers) are usually found by the bolded words in the text, so a quick scan of a few lines is sufficient to complete many reading quizzes. In addition, today's students learned when they were young that the internet provides quick answers to most questions. Indeed, there are website devoted to gathering "notes" from students (i.e., questions and answers) and then sharing them with subsequent students. (Note: if this happens to your class, you should contact the website owners and tell them to remove the content because it is your intellectual property.) In light of these obstacles, how can a teacher help students prepare?

3. PRE-CLASS ACTIVITIES

One answer is to require a pre-class activity. In my mind, ideal pre-class activities require exploration and foster curiosity. Pre-class activities can also provide different types of learning beneficial to students who may struggle with the traditional textbook-lecture-homework mode of many college classes. The pre-class activities designed for the "Descriptive Acoustics" class require students to explore an interactive simulation or do an at-home experiment. The initial implementation of these pre-class activities is described in Ref. [6]. A short description of the philosophy behind the pre-class activities for interactive simulations is given here, followed by a discussion of lessons learned about how to increase their effectiveness, especially with regards to the students' perception of the value of the pre-class activities. The benefits of using pre-class activities that involve writing are also discussed.

A. Implementation

The pre-class activities are designed to allow the students to actively engage with new material prior to class. As seen in the examples in the appendix, general directions are provided, but the experience is not scripted. Some questions are posed to give the students a clue as to key principles to think about during their investigation, but a main goal is to encourage them to be curious. In my experience, as long as the simulation runs without computer-based troubles, the students do not need detailed explanations to run the simulations, as figuring out simulations has become a "native language" of students who have grown up with smartphone apps.

Upon finishing their exploration of the interactive simulation (5-10 minutes, usually), the students write a paragraph about their experience. Writing about their experience helps solidify in their mind what they observed and supports the university's goals of "writing across the curriculum." In addition to conveying that they completed the activity, they are required to use at least three vocabulary words from the corresponding textbook reading in their paragraph, which increases their familiarity with the new terms. In the spirit of the "Just in Time" (JITT) methodology recommended by Novak, *et al*,[9] their paragraphs are submitted online one hour before class.

While the use of pre-class activities may sound good in theory, people often wonder how it works in practice. The "Descriptive Acoustics" class has up to 130 students with a wide variety of backgrounds. They receive credit for each pre-class activity based on completion, not correctness. The first week, the teaching assistants read all of the responses to ensure everyone understands the assignment. If a student writes just a bulleted list responding to the prompts, they receive half credit and an email explaining they are expected to write a full, cohesive paragraph that explains what they observed and learned in the activity. After this first week, about ten of the responses are read between the instructor before class. The online learning system gives full-credit to each student who submits their paragraph. (Credit appears in the online gradebook appears 12 hours after the submission deadline.)

By looking at student response before teaching, the instructor is better able to return to the "beginners mind" when preparing for class—often reminded of common misconceptions that students hold—allowing the instructor to be more prepared to address those during the class discussion. The pre-class activities help me fight the "knowledge curse."[14] Thus, the pre-class activities not only help the students prepare for class, but they help me prepare as well.

B. Student Perception

As with any assigned task, students may feel like the pre-class activities are just busywork unless the instructor makes a conscious effort to help the students understand their value. Over the years, different ways have been employed to help students understand the importance of the pre-class activities by integrating the pre-class activities and student responses during class.

The most straightforward way to help students value the pre-class activities is to show and/or discuss the activity during class. When showing the simulation in class, instructors should resist the urge to explain it. Instead, pose everything as a question: have the students explain what they are seeing and predict what will happen when a parameter is changed; ask what parameter should be changed to obtain a certain result; help them draw conclusions and see connections.

Another way to incorporate the pre-class activities is to use select student responses in the class discussion. One method is to make T/F questions with correct observations and common misconceptions and have the students respond using a student response system. (While some use iclickers for this purpose, the simple, color-coded ABCD card[15] shown in Figure 2 also works.)

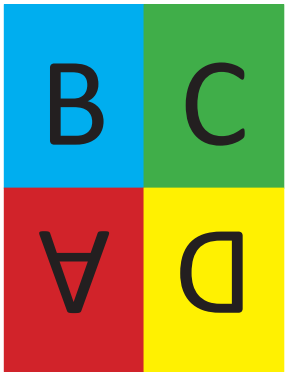

Figure 2 ABCD card - a simple student response system. The ABCD cards are made by printing the image double-sided such that when they cut in half each resulting card has all four letters. When a question is asked during class, the students turn the card such that their answer is on the top facing the instructor. (For True/False questions, A is True and B is False.) The colored cards provide a quick estimate of student understanding.

A second method of using student response to facilitate class discussion is to select students who wrote correct observations for the pre-class learning activities and then call on them in class to explain a specific portion of their experience. Not only does this help students understand that the instructor values the pre-class learning activities, it also provides a way to get more students to participate in class. At the beginning of the semester, the students are informed that they may be called on if they wrote a correct observation. (However, in this era of increased student anxiety, depression, etc., I also say that if this makes anyone hesitant or anxious about attending class (because they will potentially be asked to speak) they should let me know and I won't call on them. In my class of 130 students last semester, only three asked to not be called on.)

Another key point in helping students understand the usefulness of the pre-class activities is to remind them that incorrect answers are a great step in the learning process. Students, especially smart ones for whom school has been easy, often think that getting the right answers is the most important thing. Instructors can help students understand the role of failure (getting the wrong answers) in learning[16] and encourage a growth mindset,[17] which will help the students prepare for more challenging future assignments.

C. Benefits

As the implementation of the pre-class activities has been refined over the past six years, several benefits have been clear for the students who take advantage of these learning opportunities: increased acquisition of new vocabulary, multimodal learning, power of prediction, and spaced learning

American author and motivational speaker Zig Ziglar (1926-2012) once said, "Your understanding of what you read and hear is, to a very large degree, determined by your vocabulary."[18] When students are exposed to new vocabulary on the same day they are expected to know it, they often miss the true meaning. Before the pre-class activities were introduced, for example, three-fourth the way through the semester, a student would occasionally ask a question like "What do you mean by amplitude?" I wondered how someone could miss the meaning of a word I had used almost every class period and defined multiple times. Since the pre-class simulation in which the students adjust the amplitude slider in the PheT "Waves on a String" interactive simulation[19] AND write a paragraph using the word "amplitude," the students learn the meaning of this word, understand it in class discussions, and use it when they ask/answer

questions. The pre-class activities with a writing component help students learn the new vocabulary more quickly.

Today's students have grown up in a multimodal learning world, where textbook reading has played only a small role of their knowledge acquisition process before they reach college. When instructors provide activities that require multiple types of learning, students for whom reading is not their primary learning mode benefit greatly.[20] There are many ways to categorize learning modes,[21] but one common approach is to divide learning styles into four categories, as illustrated in Figure 3. In the read/write mode, the reading experience comes by textbook reading, and the pre-class activity writing assignment covers the writing experience. Interactive simulations provide access to the other three modes: The visual (and when appropriate aural) display of the physical phenomena is displayed, and the student interacts with it kinesthetically by moving the sliders and knobs. Aural learning is also facilitated when the interactive simulations are discussed in class. Thus, pre-class activities using interactive simulations and a writing task provide a multimodal learning experience.

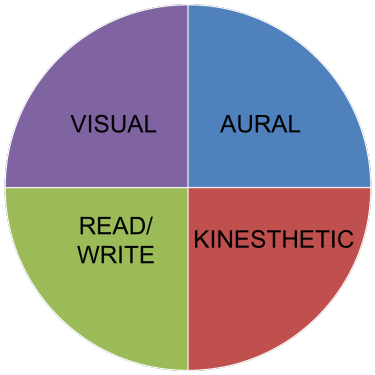

Figure 3 Different modes of learning.

In addition to providing a multimodal experience, the pre-class learning activities function as a predictive exercise. Crouch *et al*.[22] completed a study in which the power of predictions in the learning process was explained. They compared the performance and understanding of students from four parallel classes: The first class had no demonstrations; the second had demos presented with traditional instructor-supplied explanations; the third required students to write down a prediction for each demonstration before it was performed and explained; and the fourth required the predictions and the demo was followed by a discussion instead of an explanation. They found that the "no-demos" class and the "explained-demo" class students had essentially the same performance (outcome) and understanding (explanation). A statistically significant increase was achieved by the "predict" class that was enhanced by subsequent discussion. When student predictions were incorrect, they were more likely to remember the correct explanation. Their study should be applied by anyone using classroom demonstrations. The pre-class activities provide an opportunity for the "prediction" phase that can be followed naturally by class discussion.

A recent book, *Make it Stick: The Science of Successful Learning*, by Brown *et al*.[23] explains the importance of distributed practice in the learning process. He argues that traditional methods of covering material over a concentrated period of time and then moving on is less effective than a distributed practice approach in which students are repeatedly engaging with the previous topics as they learn new material. Benefits of distributed practice (illustrated in Figure 4) was termed "the spacing effect" by Dempster and Farris.[24] The pre-class activities are one way to

include distributed practice. The students are introduced to the material when they freely explore the interactive simulations. In writing about their experiences, they practice using the new vocabulary and expressing the concepts they've observed. Then they are prepared to make connections and solidify their understanding during the class discussions.

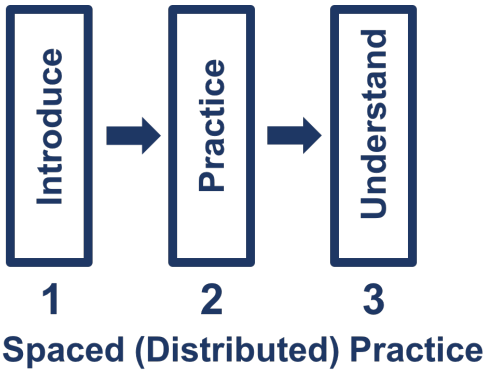

Figure 4 Illustration of spaced or distributed practice.

4. CONCLUSIONS

Interactive simulations are a powerful active-learning tool for the current generation of students but only if they have had personal experience with the simulation prior to seeing it in class. Pre-class activities provide the opportunity for the students to personally engage with the simulations, especially when then activity is mostly unscripted and encourages curiosity. The pre-class activities are particularly useful in increasing student understanding when linked to a writing component and discussed in class. These pre-class activities could potentially be expanded to include student interactions, similar to what is described in Ref. [25].

5. ACKNOWLEDGMENTS

This grateful connoisseur of interactive simulations is grateful for all those who develop them and generously share them. Thanks also to Kent Gee and Brian Anderson for useful discussions in creating and implementing the pre-class activities.

6. APPENDIX –PRE-CLASS ACTIVITY EXAMPLE

One example of a pre-class activity with an interactive simulation is provided here. Those interested in seeing the additional pre-class activities (for both interactive simulations and at-home experiments) should email the author at tbn@byu.edu.

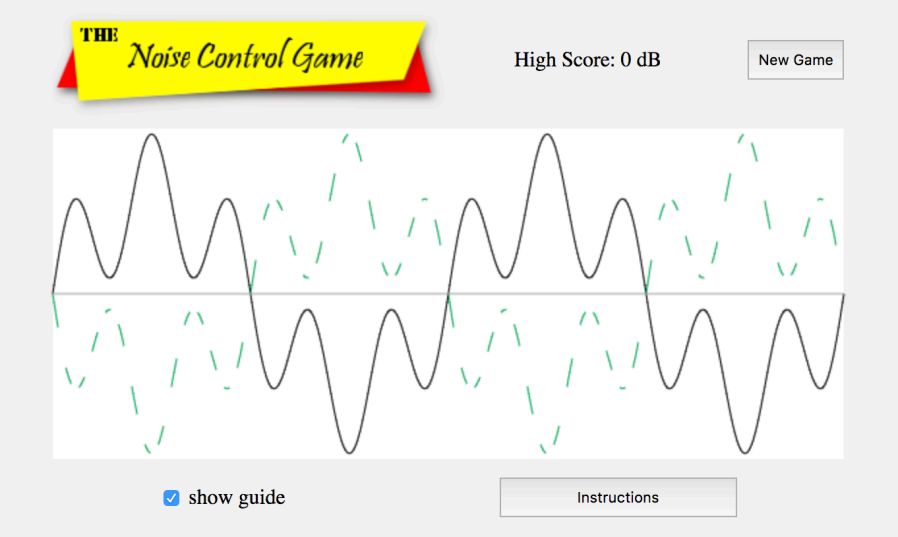

Figure 5. Noise Control Game. Interactive simulation based on the idea of Steve Nott's anti-noise game. Programmed by Caleb Goates. Available at http://goatesheard.com/ncg/

LEARNING OUTCOME: Understand how the destructive interference of waves reduces the level of sound.

METHOD: Explore how to cancel out one sound wave with another using an interactive simulation called the Noise Control Game.

RESOURCES: GO TO http://goatesheard.com/ncg/

INVESTIGATE how to use one wave to cancel another wave for a few minutes using this simulation.

- Click and drag the cursor to trace the dashed line, which represents a wave 180 degrees out of phase relative to the original wave (solid line).
- When you reach the end of the wave, a new solid line appears that is the summation of the original wave and the wave/line you drew.
- The green number that appears is the amount of attenuation in decibels you obtained, i.e. how much your wave cancelled the other wave = how much quieter you made the sound wave.
- Repeat a few times. Each time you have a different wave to cancel.
- Try it with the "show guide" button off

QUESTIONS

- How is this demonstration is related to superposition?
- Compare the ease with which you were able to cancel the different waves.
- What features of the waves were hardest to cancel?
- Do you think that matching the phase or amplitude is more important for getting a larger reduction in the noise (in decibels)?
- What implications does this have for your noise-cancelling algorithms?

ASSESSMENT: Write a paragraph or two about your observations of destructive interference. (Remember to use at least three vocabulary words from the Chapter 9-10 in your discussion.)

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