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2aED7. Use of a Just-in-Time Teaching technique in an introductory acoustics class

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The goal of active-learning techniques is to encourage the students to become involved with the material and take ownership for their learning, which fosters long-term knowledge and enjoyment of the subject. In this era of student-based learning outcomes, an active-learning approach is important because it focuses on what the students are doing to facilitate learning instead of what the instructor is trying to teach. To benefit most from class time, the students need to have the opportunity to actively engage with the material beforehand. If meaningful pre-class activities are required, it is easier to interact with the students during class. Some key methods for encouraging active learning during class include incorporating their pre-class experiences, conducting discussions, encouraging student participation, and evaluating student understanding with a response system, such as i-clickers. After the class time, students need apply what they have learned in answering additional questions on homework assignments and in hands-on laboratory experiences. Lessons learned after several years' worth of step-by-step efforts to approach these goals in an introductory acoustics class, which serves a wide range of majors as a general science elective, are presented.

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1. Introduction

Over the past few years, the authors have been making changes to an introductory, general education class entitled "Descriptive Acoustics" (Physics 167). Typically there are 60-100 students in the class, which is taught in a large lecture hall. The class covers most of the chapters in *Music, Speech, Audio* by Strong and Plitnick.[1] These changes have been driven by the need to define student-based learning outcomes, an interest in physics education research, and a desire to enhance student participation and learning. While the initial efforts are explained in Refs. [2] and [3], this paper describes in further detail the results of implementing pre-class learning activities, based on Just-in-Time Teaching (JiTT),[4] in the course over the past three semesters.

BYU, similar to many schools, has been pushing instructors to move away from course objectives and establish student-based learning outcomes. The learning outcomes focus on skills and knowledge that the students acquire in the class.[5] For the "Descriptive Acoustics" class, described in this paper, there are four learning outcomes:

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

One of the keys to selecting good learning outcomes is the use of strong action verbs, such as those underlined above. To obtain these skills, the students must have opportunities to practice them. The activities, instruction, and assessments should be designed to support the student learning outcomes. (See Fig. 1.) When the course is designed to engage the student in ways that require active participation, an effective active-learning environment is created.

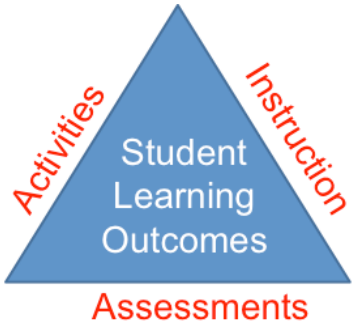

Figure 1 Course integration triangle.

Many books and articles have been written with good ideas for achieving an active-learning environment.[6,7,8,9,10] Our position is that there is not a single best practice and the potential for

each technique is determined by the teacher's personality and teaching style, the subject matter being taught, and the backgrounds of the students themselves. It is beneficial to look at a wide variety of ideas and then find things that work for a specific instructor for a specific course. For example, the application of JiTT in advanced acoustics courses[11] is different than the introductory class described here.

Over the past year, we have been impressed by how effective the use of pre-class learning activities has been in helping the students practice the skills described in the learning outcomes. The goal of optimizing the efficacy of the class discussion has been another motivating factor in these changes.

2. Transitioning from a traditional to an active-learning course.

It takes a lot of work to modify an existing course to facilitate active-learning techniques. Often the professor has to try several methods before finding one that is suited to both the class and the professor's personality and teaching style. While these might seem like drawbacks, the benefits of an active-learning course make it worth the effort. To provide a framework for discussing the transition to an active-learning course, we share the step-by-step migration from the old to the new.

The "Descriptive Acoustics" course had been a popular course for several decades when we first taught it in the spring and fall semesters 2005.[2] The first time through for each of us was a bit overwhelming because of the breadth of material covered in the course. We were fortunate to inherit a good course with great demos and reasonable exams. Our efforts the first few semesters concentrated on learning the material and figuring out what concepts were most important and the relative difficulty students have in understanding them. In the process, detailed Powerpoint slides were developed that contained the definitions, figures, tables, etc. in an organized manner. The course material was put together in a nice package but rapidly began to feel too scripted.

About this time, the student-based learning outcomes were being instigated, and we began exploring active learning techniques. Reference [2] describes our initial efforts to improve the homework assignments and the labs and the introduction of an applications paper. The most recent developments, which are the focus of this paper, are the introduction of pre-class learning activities over the past three semesters.

3. Pre-Class Learning Activities

To facilitate an effective learning experience during class, it is essential that the students come prepared. It would be ideal if the students would read, take notes on the material, and prepare questions to ask during the class discussion. In reality, this rarely happens because the students are busy with other things. It is necessary to require a graded assignment on the new material due prior to class to motivate them to consider the topics to be discussed in class.

Pre-class learning activities (LA) were designed to provide the students with meaningful exposure to the concepts before class. A LA consists of a hands-on interaction either with a simulation/applet on their computer[12,13] or a small experiment. While general directions are

provided, the LA is not completely scripted. The goal is to provide enough information that they know what to do but then to let them follow their own curiosity in completing the activity.

Each LA concludes with the assignment for the student to write a paragraph about their experiences or observations. A list of 3-5 items of things they should address in their writing is provided to guide them. For each LA, students are required to use at least three technical words from the chapter in their response. The exercise of writing with appropriate terminology is a crucial component of the LA.

A few of the LA assignments are included in appendix A to provide a sample of the format and type of activities used. Electronic copies of all the LA are available from the authors via email.

The LA responses are submitted electronically one hour before class. As with the JiTT approach, the professor reads through the responses to find common misconceptions that merit discussion during class. Examples of these misconceptions and a few well-written correct statements are chosen to share with the students. Currently, selected sentences are handed out as true/false questions and included in the class discussion. Verbal "true" or "false" responses are solicited from the students during the class discussions, and students are invited to explain their reasoning. A few additional insightful observations are often included for the students to read on their own.

While the LA were inspired by the JiTT methodology recommended by Novak *et al.*,[8] they differ in a few respects. First, the LA tend to focus on a single principal aspect of the day's material, whereas other JiTT implementations we have seen tend to cover most or all of the topics to be covered. Second, the students write a non-scripted paragraph based on their personal observations during the LA, while students completing a traditional JiTT assignment are responding to specific questions, sometimes in multiple-choice format. In addition, all the LA require the active involvement of the students in either exploring of an interactive simulation or performing an experiment.

4. Student responses

At the end of the semester, we asked the students to respond to their experiences with the learning activities. While some preferred the computer simulations and others preferred the hands-on experiments, most of the comments were positive. Here are some that express the general tone of the feedback received indicating that the students appreciated, as much as is possible with an assignment, the opportunity to engage with the material before class.

- Overall I really enjoyed the learning activities and I think that they really helped my understanding of the subject matter. I especially liked the ones where we had to figure out how it related to the topic we were going to discuss in class the next day.
- I am not one for busy work, but I thought that the learning activities really helped me grasp the concepts and prepared me with the groundwork to learn the lesson the next day.
- I felt as the though the learning activities were very effective in helping me to understand what I was reading in most of the chapters and really prepared me for class discussion as well.

- Overall, I thought the learning activities were very good practice for us to see and be able to work with what we were learning.
- In general, I very much looked forward to the learning activities for this class. They are a welcome break from the normal pencil-and-paper routine of other physics classes.

One of the components crucial to the success of the LA is the use of student responses in a portion of the class discussion. It takes time for the instructor to scan student responses and obtain a sample to share with the class in the form of a handout. The first semester, the handouts were only given on days were there were misconceptions that needed to be cleared up. But after some students expressed disappointment on not receiving a sample of student responses on the other days (those tied with observational exercises), a handout has been made each day during subsequent semesters. Here are some of the student comments regarding the use of such handouts during class.

- I appreciated all the time we spent in class addressing students' thoughts on the activity since many of us interpreted it wrong or in a way that wasn't complete.
- Discussing answers in class the next day was also helpful as I was able to see the slight differences in what I observed versus what other students observed.
- I felt the time we spent in class talking about how students responded to the learning activities was beneficial. First off, getting input from other people is always helpful because it helps me to understand things in a way I hadn't previously thought of. Also, there were often insights in their responses and connections they made between the learning activity and the corresponding chapter that I hadn't made, which not only taught me new things but also helped to solidify what I had learned.

The combination of providing hands-on exposure to the topic before class and sharing student responses during class has had a significant impact on the level of the class discussion. While some may argue that taking time from class to cover these comments limits the amount of material that can be covered during class, this has not been our experience. First and foremost, when the students have taken time to actually think about the topic and formulate a paragraph using the vocabulary, less time needs to be spent during class explaining the basic terminology. This allows for deeper-level discussions during class. Second, some demonstrations, which previously the students were exposed to for the first time in class, are now experienced by the students before coming to class. The results can be talked about and abbreviated versions can be performed in class if any concepts need to be clarified.

5. Concluding Observations

It has been a rewarding experience to introduce JiTT-inspired, pre-class learning activities in our introductory, general education acoustics class. While the development and initial implementation took more time and energy than continuing on with a traditional class, the results have been appreciated by both the faculty and the students. Although some students prefer the more organized format of systematically presented Powerpoint slides, the majority of the students agree they benefit more from class discussions centered on the pre-class learning activities and in-class demonstrations and problem solving exercises. Here are a few student

comments submitted as responses to specific learning activities that indicate they recognize benefits of the learning activities.

- I noticed that there are a lot of transducers in my life.
- Taking more notice of the sounds around me allowed me to listen with a new perspective.
- The experiment on localizing sounds turned out to me more revealing than I thought.
- I really liked this learning activity [PhET's Fourier: Making Waves[12]] because it taught the principle of linear superposition in a very effective way. I was able to see the results of my experimentation immediately, which really helped me understand how complex waves are formed.

In this era of student-based learning outcomes, it is essential that students are given opportunities to practice the skills they are expected to obtain. For the "Descriptive Acoustics" course at BYU, the pre-class learning activities have significantly improved the student experience because they allow students to define for themselves the basic terminologies of acoustics as they explore interactive simulations regarding basic physical principles and experience these principles in common situations, write about their observations using the vocabulary of acoustics, and discus the observations of their peers.

Appendix A – Sample Pre-Class Learning Activities

Unit I.2 – Simple Vibrators
Objective: Gain an understanding of basic wave properties of amplitude, frequency and damping.
Go to http://www.colorado.edu/physics/phet (or Google "phet").
Click on **Simulations**, then **Physics (**on the right side of the screen), then **Sound & Waves,** then on the **Waves on a String** picture in the center of the screen. Click **Run Now.**

Investigate the behavior of the string systems for a few minutes using this simulation.

- If you experience technical difficulties, try using Firefox.
- Click and drag the wrench to manually move the string.
- Click "Pulse" or "Oscillate" to automatically produce pulses or continuous waves on the string.
- Investigate how pulses and continuous was react to the different end conditions by selecting "Fixed End," "Loose End," or "No End."
- Investigate how adjusting the sliders for the amplitude, damping, tension and pulse width/frequency change the wave on the string.
- Use "Play/Pause" button in lower middle of the screen to stop the waves.

ASSIGMENT: Write a paragraph or two about your observations of simple vibrators. Include the following information in your paragraph. (Remember to use at least three vocabulary words from the Chapter 4 in your discussion.)

1. Define amplitude in your own words based on your observations.
2. Describe how changing the amplitude changes the wave.
3. Define frequency in your own words based on your observations of the continuous waves (seen using the "Oscillate" option).
4. Describe how changing the frequency changes the wave.
5. Define damping in your own words based on your observations.
6. Describe how changing the damping changes the wave.
7. Define tension in your own words based on your observations.
8. Describe how changing the tension changes the wave.

Unit II.10 – Speech Transmission

Objective: Perform a speech intelligibility test.
For this activity you will need a helper.
In the main room of your home, perform a speech intelligibility test with difference background noise levels.

- Have a helper stand across the room and read one of each pair of rhyming words on the table below.
- Circle the words you hear. Have your helper tell you which ones you missed.
- Increase the background noise level and repeat the test.
- Increase the background noise a bit more (but not enough to risk damaging your hearing) and repeat the test.

Regular background noise		First increased noise level		Second increased noise level	
Pest	Test	Pest	Test	Pest	Test
Fault	Vault	Fault	Vault	Fault	Vault
News	Dues	News	Dues	News	Dues
Vee	Bee	Vee	Bee	Vee	Bee
Thank	Sank	Thank	Sank	Thank	Sank
Rip	Nip	Rip	Nip	Rip	Nip
Boss	Moss	Boss	Moss	Boss	Moss
So	Show	So	Show	So	Show
Number correct?		Number correct?		Number correct?	

Assignment: Write a paragraph or two about your observations of the sound perceived under the above conditions. Include the following information in your paragraph. Remember to use technical terminology from chapter 30 in your discussion.

1. Describe your experience with the rhyming tests.
2. Rate the speech intelligibility of the room with regular background noise (i.e., the percentage of words you got correct for each case).
3. Explain how the intelligibility changed as the background noise level increased.

Unit II.1 – Resonances of the Ear
Objective: Explore how material properties influence natural (resonance) frequencies
For this activity you will need three pieces of uncooked spaghetti and three, identical, small objects that can be attached to the end of the spaghetti (ideas: small marshmallows, raisin, clay).

1. Break the pieces of hard spaghetti to produce three pieces of different lengths.
2. Place a small object on the top end of each one.
3. Hold the bottom ends in one hand such that the pieces of spaghetti stand next to each other and the masses are at different heights above your hand.
4. Move your hand from side to side in such a way as to cause the masses on the end to oscillate. (Think of an old-fashioned metronome or an upside-down pendulum.)
5. Observe the amplitude and frequency of the oscillations.
6. Experiment with moving your hand at different speeds

Assignment: Write a paragraph or two about your observations of the sound perceived under the above conditions. Include the following information in your paragraph. Remember to use technical terminology from chapter 13 in your discussion.

1. Describe your experiment.
2. Describe how the three spaghetti/mass systems responded to the motion of your hand.
3. Compare the relative natural mode (resonance) frequencies of the three spaghetti/mass system (i.e., which one had the lowest/highest natural frequency)?
4. Explain how you can tell if you excite a resonance and if you can simultaneously excite the resonance of all three systems?
5. Find a connection between this activity and a part of the ear that was discussed in the chapter.

Unit II.4 – Noise Hazards
Objective: Increase your awareness of noise hazards and hearing protection.
You will need a pair of foam earplugs for this activity. (Please remind the professor to pass them out the previous class period.)

- Listen to a pleasing, slightly loud (but not too loud) sound with adjustable volume.
- Put the foam earplugs into your ear. Notice how the sound changes.
- Remove the ear plugs and watch the short video found at http://www.exploresound.org/Home/Teachers-Parents/How-to-Wear-Earplugs.aspx
- Follow the instructions in the video to reinsert the earplugs properly.
- Listen to the same sound and notice changes.
- Turn the volume down until the sound is just audible.
- Remove the earplugs and observe the actual loudness of the sound.

Assignment: Write a paragraph or two about your observations of the sound perceived under the above conditions. Include the following information in your paragraph. Remember to use technical terminology associated with hearing in your discussion.

1. Comment on how the perceived sound changed when you first inserted the ear plugs.
2. Comment on any difference you noticed when you followed the method in the video to insert the earplugs properly.
3. Comment on approximately how much attenuation you think the earplugs provide. You don't have to give a number but instead can compare the observed loudness of the sound after you removed the earplugs to the loudness of an everyday sound.

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[1] W. J. Strong and G. R. Plitnik, *Music Speech Audio, 3rd Edition* (BYU Academic Publishing, 2007) pp. 1 - 566.

[2] T. B. Neilsen, W. J. Strong, B. E. Anderson, K. L. Gee, S. D. Sommerfeldt, and T. W. Leishman, "Creating an active-learning environment in an introductory acoustics course," J. Acoust. Soc. Am. 131, 2500-2509 (2012).

[3] T. B. Neilsen and K. L. Gee, "Application of active-learning techniques to enhance student-based learning objectives," Proc. Mtgs. Acoust. 14, 025001 (2012).

[4] G. Novak, E. T. Patterson, A. D. Gavrin, and W. Christian, *Just in Time Teaching*, American Journal of Physics, **67**, 937-938 (1999).

[5] Brigham Young University has placed a great deal of emphasis on learning outcomes as can be seen at http://learningoutcomes.byu.edu (Viewed 21 March 2011.) Guidelines for writing learning outcomes can also be found at this page.

[6] C. H. Crouch and E. Mazur, "Peer Instruction: Ten years of experience and results," *Am. J. Phys.* **69**, 97-977 (2001).

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[11] K. L. Gee and T. B. Neilsen, "Application of Just-in-Time Teaching to advanced acoustics courses," Proc. Mtgs. Acoust. **18**, submitted 2012.

[12] The PhEt team, http://phet.colorado.edu/en/simulations/category/physics/sound-and-waves (Viewed on 1 October 2011.)

[13] Paul Falstad, "Education math and physics applets," found at http://falstad.com/mathphysics.html (Viewed on 1 October 2011.)