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Considering Best Practices in Technical Ear Training

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Considering Best Practices in Technical Ear Training

Cover Page Footnote



Considering Best Practices in Technical Ear Training

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ABSTRACT

Technical Ear Training (TET) is a new approach to preparing audio students for the professional environment. Systematic training develops the listening skills of student engineers and advances them as sensitive listeners. However, the current educational landscape lacks a nationally recognized curriculum that addresses specific characteristics of technical ear training. These characteristics include frequency identification (both boosts and cuts), gain, phase shift, delays, reverb times, and dynamics parameters. Targeted ear training methods can help students refine their technical listening skills and gain an increased technical vocabulary. This paper investigates multiple approaches to technical ear training, including data from an actual class using some of the methods presented in the paper; and it argues for a multi-faceted approach to ear training using new training software, analytical exercises, and headphone/speaker standards.

The teaching model I applied in my professional practice offered a one-semester TET program that included frequency boosts and cuts identification with both pink noise and music. Results of the in-class assessments, online quizzes, and exams indicate an improvement with identifying frequency boosts and cuts in both music and pink noise. These data indicate that students are ready for new listening challenges, and that +10dB boost and -10dB cuts of pink noise can be removed by mid semester.

INTRODUCTION

Technical Ear Training (TET) (Corey, 2016) for audio, sound and music production helps students develop a sophisticated set of listening skills focused on the equipment and processes relating to music production. TET differs from traditional music ear training in that musical ear

training teaches students identify musical elements of pitch, rhythm and harmony whereas TET helps students identify sonic events such as mix placement and the effects of signal processor applications. Experienced engineers have skill sets that include increased reaction times to assess sonic differences and a broad range of vocabulary to communicate in discipline-specific unambiguous terms in a studio or media production facility. Walzer (2015) states that no two ear training programs are exactly alike, and each program develops a curriculum based on both the needs and scope of the program. Research on training effectiveness and the need for standardization is an active topic among ear training scholars (Quesnel 2001; MARUI 2018; Iwamiya 2003; Walzer 2015)

This paper reports how students' perception of sound developed when exposed to a semester of audio frequency training using pink noise and music. Husson University is a private non-profit school with approximately 3500 students in Bangor, Maine. This class is part of the audio engineering program within the School of Mass Communications. The 15-week Critical Listening class consisted of weekly in-class and homework listening exercises, readings that introduced new audio vocabulary regarding mixing, and deconstructing mixes by analyzing song forms and their arrangements using color graphics that represented the various sonic stages throughout a song. My research investigates how my curriculum helps students develop their sensitivity to frequencies in pink noise and music.

BACKGROUND

Over the past two decades, methods of TET have become well-established parts of audio program curricula in schools of music, communication, and engineering with specializations in recording arts, acoustics, software development, and sound design. However, TET is considered to be in its infancy in terms of formal education (Quesnel 2001; Walzer 2015). Research on training effectiveness has become an active topic by ear training scholars (Kim 2015; Quesnel 2001).

Unlike traditional musical ear training that has been standardized over the years, technical ear training lacks such consistency (Walzer 2015). Musical ear training has had decades to develop sequences of defined aural skills standards that can be seen in almost every music school. Common training includes identification and dictation of intervals, melody, harmony and rhythmic figures. Students usually take a sequence of these classes which become more technically demanding and complex over time.

One early example of a TET curriculum can be found in the Chopin Academy in Poland. In the United States, David Moulton introduces a system of TET in his *Golden Ears* book and, more recently, in computer-based interactive and computer adaptive training software (Quesnel 2001; Kim 2013). Moulton's *Golden Ears* TET program offers a system that educators can implement in a classroom and lab scenario. Moulton covers a wide variety of listening parameters including amplitude, stereo, equalization, distortion, compression and time-based listening examples. This training program's flaw is its static content and delivery method consisting of premade wave files on a compact disc. Consequently, students can memorize the sequence of samples and thus seem to demonstrate a competence they have not actually achieved.

Quesnel's study of computer-assisted training offers a history of formal TET training including definitions of terminology associated with TET curriculum, and focuses on boosts and cuts of frequencies (Quesnel, 2001, pg.8). Additional topics of study includes perceptual dimensions of timbre (Grey 1975; McAdams 1995; Hajda 1997) and spectral centroids - a measure of the distribution of spectral energy (Kendedall and Carterette 1996). Quesnel identifies the nine frequency values or critical bands that are used in TET and further associates the boosting or cutting of these bands with the term "formant" -- the "frequency of the centroid of a gross concentration of spectral energy" (Quesnel 2001, pg.15). Quesnel's research found the difference among listeners' perception is large at first, but diminishes as the class moves forward. He found that TET is a performance-based training that deals with both accuracy and response time, and that the better listener will take fewer steps in identifying correct answers when tested. In the end he suggests that offering listening drills that have more than one boost

and/or cut per listening example would be beneficial as the class advances. He also states that identifying frequency cuts is comparatively more difficult for most students than identifying boosted frequencies (Quesnel 2001, pg.102).

LITERATURE REVIEW

Literature indicates that institutions are beginning to refine their pedagogical approaches and delivery of TET (Kim 2015; Corey 2013; Iwamiya 2003) . The success of TET is supported by anecdotal evidence, and its effectiveness has been verified by a number of studies ranging from analyzing performances in 15-week TET classes to programs that are oriented towards individualized training. In an attempt to broaden the dialogue and refine pedagogical processes, researchers are now sharing their teaching approaches to TET in papers and textbooks (Quesnel 2001; Iwamiya 2003; Kim 2003, 2015; Corey 2010; 2013). Other studies raise questions about training effectiveness (Quesnel 2001; Kim 2015) as well as the need for a more balanced and standardized national curriculum (Walzer 2015; Marui 2018) and delivery of TET content(Kim 2015; Marui 2018).

Two Methods of Frequency Ear Training: Identification and Matching

Moulton's program consists of a series of pre-recorded listening examples with pink noise and music. Nine critical bands are used with a 12dB boost or cut. Students listen to the examples and indicate which frequencies they believe are being boosted or cut. This method has been used at institutions such as Full Sail University and New York University. The medium for this training has shifted from delivery via CD to computer-based training. Examples of this shift in format can be found in programs such as Rene Quesnel's *Timbrel Ear Training* and Jason Corey's *Technical Ear Training and Critical Listening* books; both include supplementary software that address various listening test parameters reflective of Dave Moulton's *Golden Ears*. In addition to textbooks, an impressive number of software apps address these ear training goals; examples of such apps include Auricula, Quiztones, Trainyourears.com, and Sound Gym.

Two common methods for training frequency identification are internalizing frequencies and matching frequencies (Quesnel 2001; Corey 2010, 2013; Kim, 2015). Internalizing frequencies involves repetition and familiarity with one's playback system (e.g., headphones or speakers). In matching, students use training software with an equalizer. They can listen to a sound sample and attempt to match what they hear with by adjusting the equalizer. The student has a tactile experience, time to consider what frequency is actually being altered, and the opportunity to engage an equalizer to achieve the adjustment that they think will match the altered example. This approach helps students become more confident with the decision-making and decreases their reaction time. Matching frequencies is a stepping-stone towards what Corey calls "Isomorphic mapping," which is the ability to hear a recording, aurally deconstruct the mix or sound, and use one's audio tools to recreate that sound (Corey, 2010).

Individual Training vs. Group Training

Literature discusses both group and individual training methods (Kim 2013; Quesnel 2001). Regarding classroom (group) settings, Corey (2013) finds value in class discussion when listening to examples. Terminology is reinforced when students discuss what they are hearing among their peers. Group training can lead to the introduction of new descriptors and create "soft" competition among students, where they compete for scores, but do not become too invested in besting student opponents. (Kim, 2013).

One drawback to group learning is that some students have trouble identifying specific listening examples. If class discussions move too quickly, some students may not have the opportunity to identify and match sounds within a classroom setting.

Students who are taking a hybrid or online class will experience training in a different way. Most ear training software works with randomized sound examples and students are typically required to identify a certain percentage of frequencies correctly. Adaptive software helps individualize training because it enables students to work at their own pace. This software

works by quickly identifying what the students are struggling with and focuses training in those areas (Quesnel 2001; Kim 2013, 2015). For example, if a student has a hard time identifying 500Hz cut in music or pink noise, the software will include more examples of this frequency until the student becomes consistent with the identification.

The Need for a Standardized Vocabulary

Another recurring task amongst researchers is building a working vocabulary associated with audio. (Iwamiya 2003; Porcello 2004; Corey 2010, 2013; Kim 2013). Terms like “timbre” and “sonic signature” are often unclear for beginning audio students. However, classroom discussions as well as properly placed literature within the curriculum can help increase students’ awareness of a term’s meaning and use. In an attempt to address student communication, Iwamiya (2003) describes the expectations of his institution’s program:

The sound professional should expect to come across numerous technical terms expressing acoustic features, e.g. sound pressure level, frequency, and spectrum. When a sound professional needs to explain an auditory difference, this difference should be expressed using the appropriate technical term. (Iwamiya 2003, pg.27)

Porcello’s paper further demonstrates the importance of language and professional vocabulary by recording, transcribing, and then comparing conversations between two groups in a recording studio setting: first, a group of experienced engineers and second, an experienced engineer with a first-year sound recording technology student. Porcello identifies communication strategies two seasoned professionals use and compares them with the conversation between the professional and student (Porcello, 2004). It is clear that the student struggles to understand the directions given by the experienced engineer and his success in identifying sound references is limited (Porcello 2004, pg. 745). The two experienced engineers keep the conversation short and free of lengthy descriptors because they have a mutual understanding of what needs to be achieved and what equipment is needed to accomplish the task (Porcello 2004, pg 752).

Audio engineering textbooks have always acknowledged and included the unique vocabulary of descriptors like “fat,” “thin,” and “muddy;” but recent TET textbooks dedicate chapters to communication strategies and writing descriptors to be used when aurally deconstructing a mix. Corey (2010) emphasizes the importance of vocabulary throughout his book. One goal is to sensitize students to sound, but the ultimate goal is to solidify the concept of isomorphic mapping, which is an engineer’s ability to form mental links between particular features of sound quality and specific types of signal processing or equipment (Corey 2010, pg.8). Strong communication skills can be supported by a glossary of vocabulary that can only be obtained through listening and knowledge of descriptors (Corey 2010, pg.135).

A Call for a Balanced and Standardized Curriculum

Questions have been raised about the effectiveness of TET programs, whether looking at the entire program or at class sequence (Quesnel 2001; Kim 2013; Walzer 2015). Quesnel and Kim offer data that supports student improvement but also indicates the need for more research on training effectiveness (Quesnel 2001, pg. 96; Kim 2015, pg.113). One of the largest challenges TET classes face is class time limitations. Current research indicates that introducing targeted exercises reduces the time needed to demonstrate competency in a specific topic which allows students to experience additional TET topics. Kim’s (2015) research also includes technology used by students such as headphones and playback systems. He concludes that the quality of the students’ technology plays a factor in their ability to be successful in TET training.

Walzer (2015) points out a lack of standardized rubrics and class sequences that address aural skills in music production and audio engineering programs. By standardizing TET, institutions can create rubrics that meet accreditation standards while preparing students for the work-force environment and guiding administrators who usually “lack awareness of the required skill sets” (Walzer, 2015 pg. 43) Walzer further points out that the reason that standardization has not been established in undergraduate music technology degrees is “largely due to the multidisciplinary focus of sound-related fields” (Tough 2010, pg. 152). Walzer adds that while each institution will have its own approach to evaluation, a “codified system would be ideal” and

imperative for successful programs (Walzer 2015, pg. 45). A codified system would help develop a more unified set of benchmarks for evaluating the aural capabilities of each student. Such an approach would offer a system of evaluation for reluctant institutions that are accustomed to musical ear training standards and to satisfy accrediting bodies when evaluating a program.

Walzer suggests what a well-rounded program/curriculum would contain. Such a course may

incorporate a tiered system of memorization of frequency bands, microphone polarity patterns and placement, instrument and amplifier types and common problems encountered in the recording environment including distortion, phasing, clipping, jitter, buzzing and noise along with recorded examples of each. (Walzer 2015, pg. 45)

Walzer supports Corey's finding in regards to the benefits of group discussions, and further suggests that "specific aspects of the audio presented in an aural skills class should include supplemental discussions of how sound manipulation influences creative decisions dictated by equipment and workflow choices, an historical and cultural context, and musical tendencies" (Corey 2012, pg. 1–4). Adding an "historical overview of recording technology and changes in perceptions of music creation may be appropriate within the class." He concludes that audio-specific TET course sequences should embrace a "systematic approach that guides students towards autonomy in making creative, aesthetic and technical decisions through relevant lab work, historical and social context, and independent discovery "(Walzer 2015, pg. 46).

Kim (2013) suggests that individualized training using adaptive feedback is more effective than classroom-based courses. Adaptive software focuses on what the trainees are struggling with. In 2015, he proposed that standardized testing should be designed to determine the accuracy and time required to manipulate a given sound source's spectrum and match it to a reference signal using a three-band parametric equalizer. This study investigates whether individualized technical ear training improves ability to manipulate spectral balance with an audio equalizer and assesses trainee improvement with a new standardized listening test. In

Kim's third paper (Kim and Olive, 2015), adaptive feedback allows the software to focus on what the trainees are struggling with. He suggests steps towards standardization of monitoring the students' progress.

Further argument has been made in support of standardization by Marui and Kamekawa (2018), who investigate the correlation between students' subjective ratings on the TET task difficulty and physical measures calculated from the sound materials used in the training. They suggest that one of the current issues with training is the educators themselves. In "designing the successful course in an educational institution, it is essential to have the gradual increase of the task difficulty." In the past educators were not formally trained, but rather built curriculum as needed from a limited amount of previously published resources. However, "the objective measure of the difficulty is still not known, and thus the tasks are decided by the instructor's own ears and experiences, which leads to inefficiency when students want to train themselves in the instructor's absence" (Marui and Kamekawa 2018, pg. 5). Skill set bench marks strengthen student outcomes and offer a streamlined approach to lesson delivery. One might argue that because of the lack of standardization, a teacher-led learning course can be problematic due to the shortcomings of the instructor's senses and/or class organization.

Methodology:

Organization of Student Tests

In response to the literature, I identified several concerns that need to be addressed in the design of student testing and training. I realize that I cannot cover every topic of TET in a 15-week class and there is no research concluding how much time should be spent on each TET topic. While I expected students to purchase professional quality headphones, I could not demand a specific price point or model of headphones. Lastly, while most students cooperated respectfully, the maturity level of students varied and likely played a role in the outcomes of test results and, thus, my research.

I chose **frequency identification** as the training topic for this research as it is one of the most popular topics of study found in the literature. My main concern was to develop a sequentially regimented and systematic approach that is clear for the student to understand. Class activities consisted of in-class listening, reflection through class discussion, mix deconstruction assignments, listening homework, online quizzes, and two exams. I used the results of in-class quizzes, homework and exams to determine if there was an indicator that would tell me whether or not I could change topics within the 15-week class.

There were four modes of test delivery:

1. In-class quizzes (Group)
2. Homework Drill Sets (Individual)
3. Online Quizzes (Individual)
4. Mid Semester and Final exam (Group, weighted heavily in the grade schema as well as to assess student progression)

In Class Quizzes

Husson's in-class quizzes are given at each class meeting. Students are asked to identify 10 sound examples that contain 10 decibel boosts and attenuations of specific frequencies using both pink noise and music. The assessments are broken up into four categories and we only assess one of the categories each week. These categories are rotated so that the students will have completed three categories over a fifteen-week semester.

1. +10dB boosts using pink noise
2. +10dB boosts using music
3. -10dB attenuation using pink noise
4. -10dB attenuation using music

This exercise is referred to in class as a *drill set*. Prior to class, students receive a link to the quiz, administered as a Google survey. Before the quiz, a warm-up track of the material is

played twice. Then I play the quiz (twice) which is constructed from the warmup samples but in a random order. In music-focused weeks, I open discussion and ask students their thoughts on what they are hearing. My aim is for them to use terminology and adjectives/descriptors introduced in Corey's *Audio Production and Critical Listening*. After I play the quiz examples twice, students enter their answers on the google quiz via their phones, tablets, or laptops. Once answers are submitted, I play the example one more time, showing students the class results of the quiz. Students are encouraged to share how they determined their answers during this process. The class results are kept anonymous to encourage students to participate. A google survey summarizes the student responses in a pie chart. As the examples are being played, students can see whether or not they achieved a correct response and how they performed compared to the rest of the class. This exercise gives students the opportunity to listen to the material and helps them internalize sonic signatures.

This class takes place in a typical classroom that has minimal acoustic treatment. High-quality mastering monitors are mounted on the wall. The enrollment cap for this class is set at 24 students.

Online Listening Homework Drill Sets

Each week students are assigned listening homework that they do individually. We used Auricula ear training software that was installed as a site license throughout the university campus. The drill set homework mirrors the in-class materials used that week.

Auricula works as a plug-in in a variety of DAWs. In this case I created 12 GarageBand sessions containing pink noise or music depending on the weekly schedule. The Auricula interface plays random boosts or cuts which students need to identify (see Figure 1). These assignments were treated as pass or fail and accounted for 15% of the student's course grade.

Auricula's grading program includes a time stamp feature to ensure students do not cheat. While Auricula is not an adaptive software, it does randomize examples, ensuring that students

are unable to memorize sounds. Students are allowed unlimited attempts to reach a score of 80% or above on a drill set. They are given a week to accomplish this homework assignment.

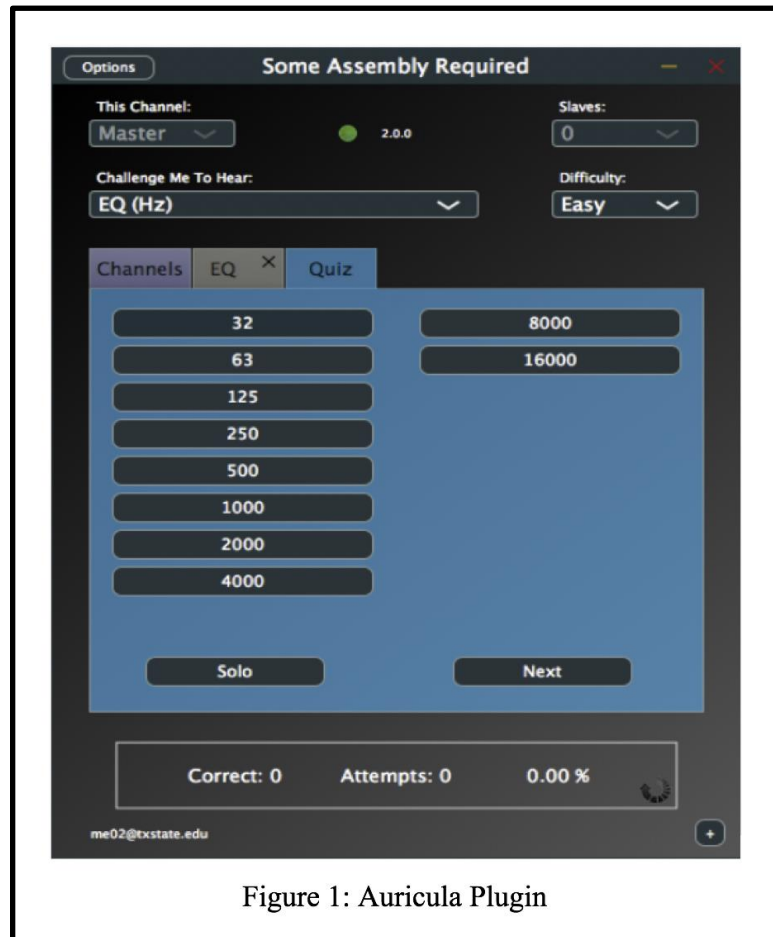


Figure 1: Auricula Plugin

Online Quizzes

At the end of the week, I post a third quiz containing the same audio material that we used in class. This quiz is given on our university's learning management system, *Canvas*. The sound file is available for them to audition as many times as they want, which allows students to prepare and thus reduce anxiety. Grading is not absolute, and students can receive partial credit if their answers are within an octave of the correct answer. *Canvas* is able to generate Excel data in addition to a basic summation of student performance for each question. This allows me to identify any examples that are difficult for the class and find patterns of behavior within the results.

Midterm and Final Exams

Midterm and final exams were in the same format as the in-class group drills. However, all four types of listening examples are used during the exams. The exams include 40 listening examples -- ten examples each of +12dB pink noise, +12dB Music, -12dB pink and -12dB music. The exams allow the students to demonstrate their listening abilities and their familiarity with how these examples sound in the room and through speakers. The weight of these exam grades are valued much higher as an incentive for the students to perform well.

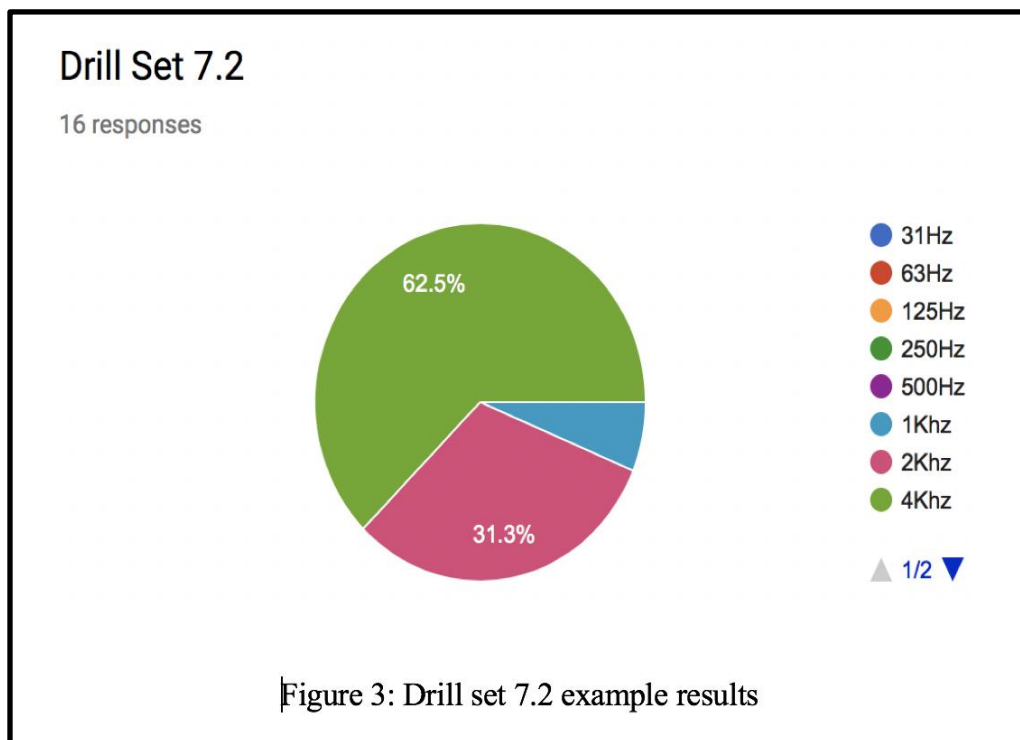
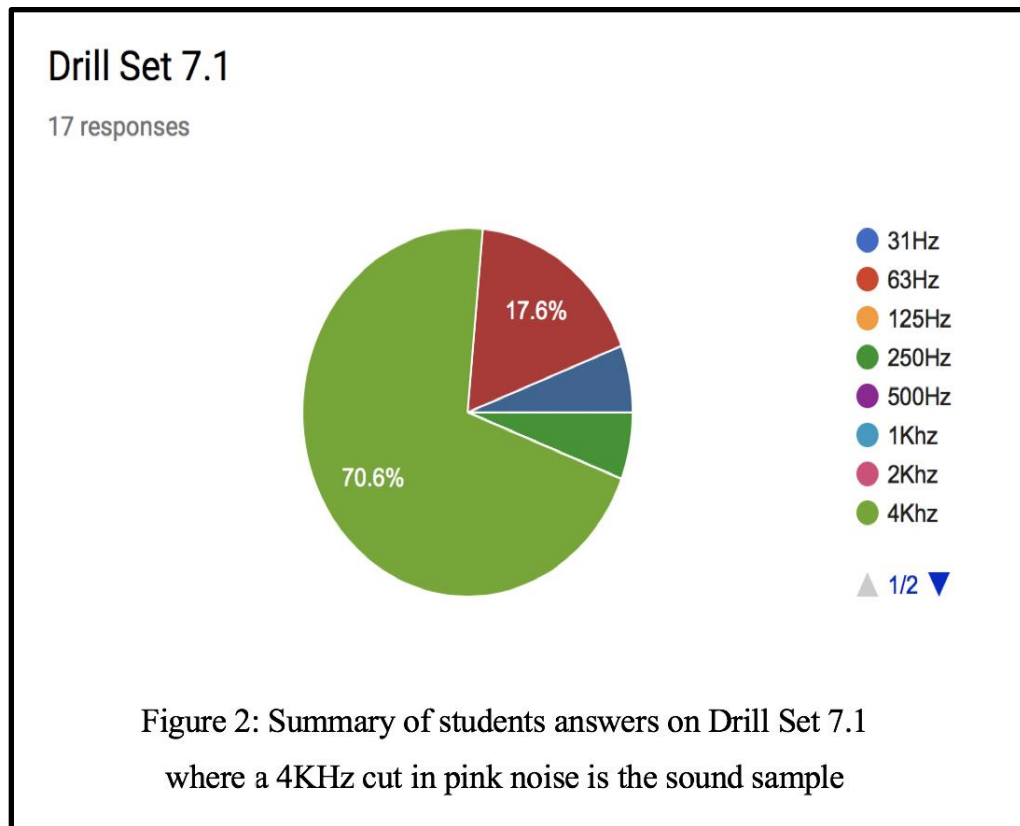
RESULTS AND DISCUSSION

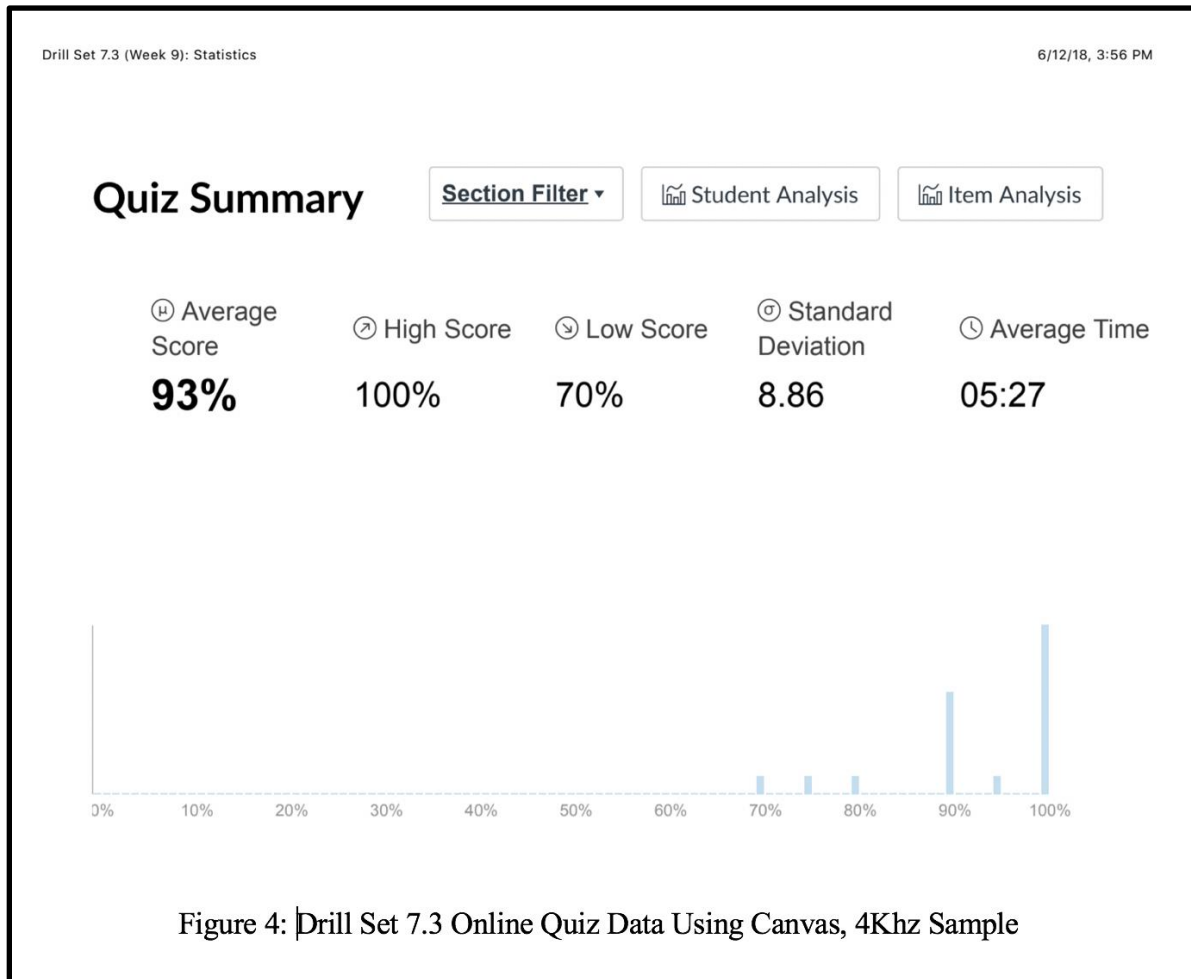
Each music example can offer challenges to students for a variety of reasons. Challenges include trouble discerning frequency changes in sparse or busy sections of songs, distractions due to genre or style, sonic aesthetics, dynamic changes, transitions from one section to another, lyrics, and solo instruments. Examples were chosen to minimize distractions due to lyrics, extreme dynamics and the overall performance style of the song. As I stated earlier in the methodology, student maturity does factor into the results.

In-Class Quiz Results

Data indicate that the repetition and consistency of class meetings (which for this class were twice per week) played a significant role in the students' TET development. The in-class listening drills allowed them to participate without being identified or singled out, and there were no grades attached to this activity. My intention was to create an environment where students could give an honest attempt without being pressured publicly. As the semester progressed soft competition developed between students. The majority of students wanted to do well, and class discussions were common during and after the process.

Figure 2 is a photo of the summary the answers of a listening example from Drill set 7.1, a pink noise cuts quiz. Students listened to ten examples and identified whether the samples are 31Hz, 62Hz, 125Hz, 250Hz, 500Hz, 1KHz, 2KHz, 4KHz, 8KHz, or 16KHz. In this example, a 4KHz cut in pink noise is the sound sample students needed to identify. Since the frequencies are never repeated within a quiz, the question arises whether students use deduction if they are experiencing trouble identifying a frequency. Drill set 7.1 was presented on a Monday while examples from Drill Set 7.2 occurred on the following Wednesday. In Figure 2 (Drill Set 7.1), 70.6% of 17 students chose the answer 4KHz. After the quiz we review the answers and students are able to see what percentage of the class chose the right or wrong answers. Statistics from Drill Set 7.2 (Figure 3) shows a decrease in identifying 4Khz. This decrease may be due to a number of factors including lack of effort focus, or familiarity with the room and speakers. While this particular example may not show class improvement between the two days, results from the third quiz (DS7.3 – Figure 4), which was online and given by the end of the week, shows improvement in identifying 4Khz. The higher percentage of correct answers on may be due to using headphones instead of being in class.





Auricula Homework Submission

The purpose of assigning Auricula as homework is to continue the training outside of the classroom. The weight of the grade for these assignments is set low; students pass with a grade of 80% or higher. Students can take the quiz as many times as they want within a week. I viewed this homework as practice, much like that of a music student practicing their instrument. Unfortunately, I did not collect the data from these assignments to add to the paper. I did find that while the weighted grade of this homework was low in regards to the overall class grade, most students did submit the work.

In the example in Figure 5, the plugin is creating boosts of 12dB in pink noise or music and the students must identify 8 out of 10 frequencies correctly. Note that this software randomizes and repeats frequencies, unlike my prepared drill sets which only offer each frequency once per quiz. The date and time the student began the quiz is noted at the top of the report and the end time is shown at the bottom. The “parameters” section indicates the ten frequencies that the software used. Below the list of used frequencies, Auricula gives the type of equalizer, in this case a peaking EQ that is boosting the signal by 12 decibels, and shows the defined Q or slope at which the signal is being boosted. Below the parameters section is the student’s results. In this case the student successfully chose eight out of ten frequencies correctly. This student did have trouble with 4KHz.

```

Exam Started...
2015-10-21 - 21:48:18
*****
parameters:
+ ENABLED 31 - 1
+ ENABLED 63 - 2
+ ENABLED 125 - 3
+ ENABLED 250 - 4
+ ENABLED 500 - 5
+ ENABLED 1k - 6
+ ENABLED 2k - 7
+ ENABLED 4k - 8
+ ENABLED 8k - 9
+ ENABLED 16k - 10

EQ Type: Peak
Boost/Cut: +12 dB
Q: 3 ( default )

*****
01 / 01      100%   +   16k was correct!
02 / 02      100%   +   63 was correct!
03 / 03      100%   +   63 was correct!
04 / 04      100%   +   8k was correct!
04 / 05      80%    -   4k was wrong, and should have been [ 2k ]
05 / 06      83%    +   63 was correct!
06 / 07      85%    +   16k was correct!
07 / 08      87%    +   16k was correct!
07 / 09      77%    -   4k was wrong, and should have been [ 1k ]
08 / 10      80%    +   2k was correct!

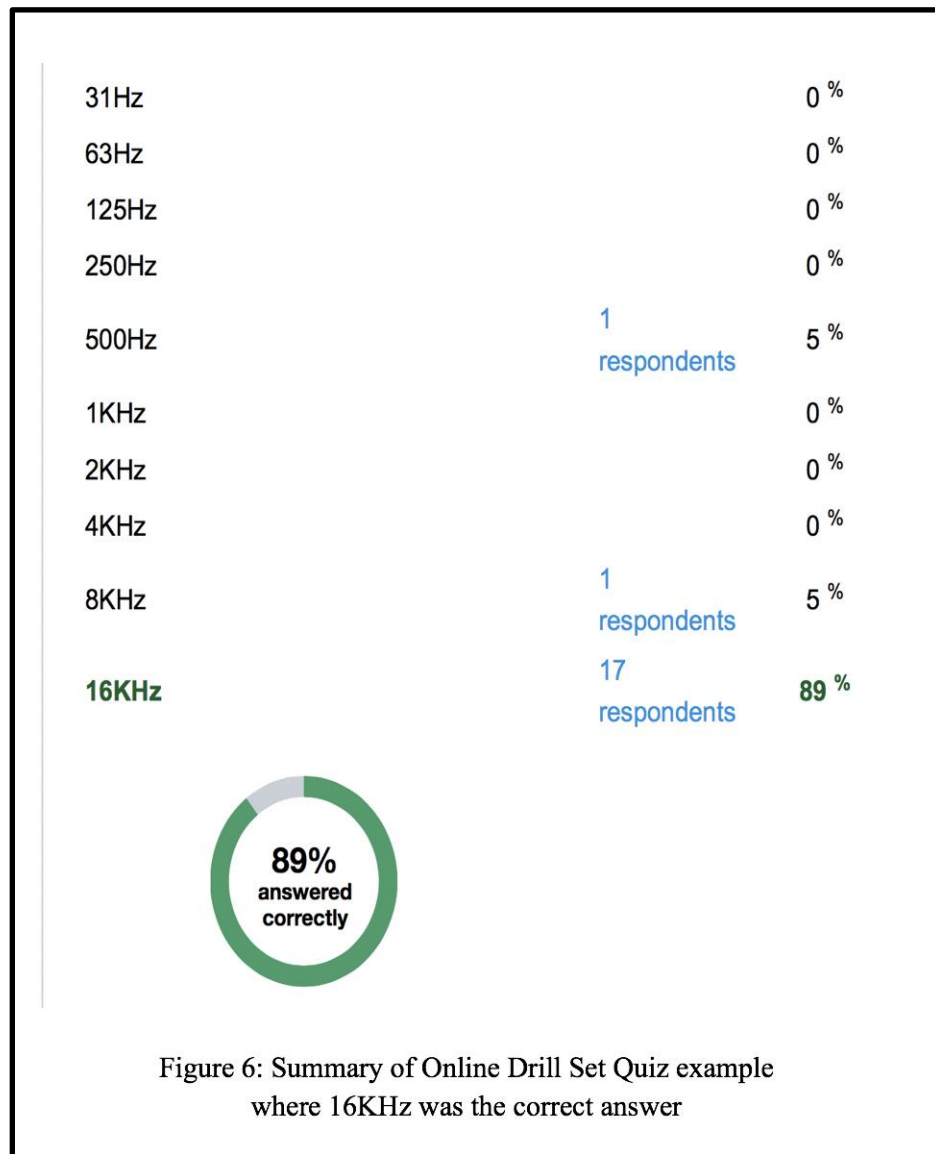
Exam Ended.
21:50:08

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Figure 5: Auricula Generated Homework Quiz Results

Online Drill Set Quiz Example

At the end of each week, I post an online quiz through Canvas containing the same material I use in the in-class quizzes. This online quiz allows students to revisit material they struggled with in class and demonstrate their familiarity with the frequencies within the specific material. Figure 6 shows a summary of what all students chose for a specific frequency in the online quiz. In this case 16KHz was the correct answer.



Unlike the Auricula homework, the Canvas quiz was a set recording that did not randomize or repeat frequencies. Again, the experience was intended to mirror the in-class drill sets. Another the Auricula homework, data from Canvas quizzes were collected.

Online Quiz Results Summary

Table 1 below shows the percentage of students that chose the correct frequency. NA stands for Not Available; these drill sets fell within Midterm or Final exam week. I gave partial credit if the student's answer was within an octave of being correct. Notice the increase in identification accuracy between the first and third examples. For example, highlighted in yellow, the music boost (DS 2.3 and DS 10.3) and music cut (DS 4.3 and DS 8.3) quiz results show an increase in students' ability to correctly identify frequencies. Music examples are the most challenging for the students, but students showed improvements in identifying frequencies in all drill sets.

Table 1: Percentage of students choosing the correct frequency

Pink Noise boostDS 1.3 (week 1)

31Hz 84%

125Hz 84%

2KHz 84%

8KHz 84%

DS 5.3 (week 5)

100%

88%

94%

100%

DS 9.3 (week 9)

100%

95%

95%

89%

Music BoostDS 2.3

31Hz 5%

250Hz 0%

4KHz 26%

8Khz 0%

DS 6.3

NA

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--

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DS 10.3

55%

75%

65%

35%

Pink Noise CutDS 3.3

250Hz 75%

2KHz 65%

4KHz 60%

8KHz 75%

DS 7.3

90%

85%

65%

85%

DS 11.3

63%

81%

88%

94%

Music CutDS 4.3

250Hz 5%

500Hz 20%

4KHz 15%

16KHz 10%

DS 8.3

35%

59%

41%

53%

DS 12.3

NA

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Midterm and Final Exam Results

Midterm and Final exams were made up of four groups of listening examples with ten audio examples in each category. The results of these tests are shown in Table 2. For example, on the Midterm in Pink noise +10dB boost category, eight students (40% of the class) scored 100% correct while nine students (45% of the class) scored 80% correct. There is a clear improvement from midterm to final exam.

Table 2: Midterm and Final exam results

First Half (6 weeks) of Semester Midterm Exam Performance Out of 20 students	Second Half (6 weeks) of Semester Final Exam Performance
<u>Pink Noise +10dB boost</u> 8 earned 100% or 40% of class 9 earned 80% or 45% 1 earned 50% 2 earned 40%	<u>Pink Noise +10dB boost</u> 12 earned 100% or 60% of class 8 earned 90% or 40%
<u>Pink Noise -10dB cut</u> 7 earned 100% or 35% of class 5 earned 80% or 25% 1 earned 70% 4 earned 60% or 20% of class 2 earned 50% 1 earned 30%	<u>Pink Noise -10dB cut</u> 9 earned 100% or 45% of class 8 earned 90% or 40% 1 earned 85% 2 earned 70%
<u>Music +10dB</u> 1 earned 100% 1 earned 80% 2 earned 70% 2 earned 60% 1 earned 50% 1 earned 40% 4 earned 30% 1 earned 20% 4 earned 10% 3 earned 0	<u>Music +10dB</u> 2 earned 75% 2 earned 65% 3 earned 60% 3 earned 55% 4 earned 50% 1 earned 45% 3 earned 40% 1 earned 30% 1 earned 10%
<u>Music -10dB</u> 1 earned 70% 1 earned 60% 3 earned 40% or 15% 5 earned 30% or 25% 5 earned 20% or 25% 3 earned 10% or 15% 2 earned 0	<u>Music -10dB</u> 1 earned 65% 4 earned 60% or 20% of class 2 earned 55% 2 earned 50% 2 earned 45% 3 earned 40% or 15% 2 earned 35% 3 earned 30% or 15% 1 earned 25%

These results show that students' sensitivity to pink noise boosts and cuts improved noticeably over the course of the semester. The students' improvement in identifying music boosts and cuts was not as great as that of their progress on identifying pink noise. An increase in

sensitivity in the lower percentage areas can also be seen between exams. During the music boosts section of the midterm exam, three students were unable to recognize frequencies; but by the final exam, all students were able to recognize at least one frequency. This result indicates students improve from the mid-semester to the end of the semester due to the extended TET training.

CONCLUSIONS

The data shows that my method of combining group and individual training methods, testing students in class with a sound system and individually by headphones improved student's sensitivity to frequencies within a 15-week semester. Results indicate that a full semester of pink noise boosts and cuts (12db) is unnecessary and that by mid semester, we should move to another listening topic. One option is to decrease the boost and cut of pink noise to +/- 6dB or introduce a new listening parameter such as delays, dynamics, phase or gain.

While I addressed and applied targeted vocabulary within the class, I did not record conversations or collect written student work samples to examine their development in vocabulary for this paper. More research should be done on the effects of implementing targeted vocabulary. I also did not collect data on student's headphone models. In the future, collecting this data may present new information in support of standardization of monitoring technology. Finally, the software tools I used allowed the questions to be randomized and repeated, but not adapt to the students' answers. Future research should examine the effects of adaptive versus non-adaptive software. All of the suggested future research can lead to an overall standardization of curriculum. Standardization of TET curriculum would help institutions ensure consistency in student outcomes, and create benchmarks that institutions can recognize and follow while satisfying accrediting bodies.

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