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Summative Evaluation of *Global Soundscapes: Mission to Record the Earth* Adapted for Visually Impaired Students

Report for
Purdue University
Foxfire Interactive

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We would like to thank the staff at the EcoTarium for implementing the interactive theater show and post-show sound walk activity and thank the students and staff of Perkins School for the Blind for their participation in the summative evaluation of the *Global Soundscapes* adapted programs.

EXECUTIVE SUMMARY

Supported by the National Science Foundation, the *Global Soundscapes! Big Data, Big Screens, Open Ears* project employs a variety of informal learning experiences to present the physics of sound and the new science of soundscape ecology. The interdisciplinary science of soundscape ecology analyzes sounds over time in different ecosystems around the world. The major components of the *Global Soundscapes* project are an educator-led interactive giant-screen theater show, group activities, and websites. All components are designed with both sighted and visually impaired students in mind.

Multimedia Research, an independent evaluation firm, implemented a summative evaluation with visually impaired students from Perkins School for the Blind at the EcoTarium in Worcester, MA. Using real-time observations and a post-experience questionnaire, the evaluation assessed the influence on 10 visually impaired teenagers of a 45-minute interactive, sound-based, giant-screen theater experience followed by a one-hour "sound walk" activity. The general goals of the evaluation were to assess engagement, appeal and interest; knowledge of soundscapes; and potential future behavior related to soundscape ecology.

Key Findings of Engagement, Appeal and Interest

A majority (70%) of visually impaired students either liked the *Global Soundscapes* interactive theater show "a lot" or a "great deal." Through the 45-minute show, the students were observed to be engaged with the audio sounds and audience interactivity, and about half were verbally responsive to the presenter's questions. Students most liked hearing different sounds (60%), but some students noted discomfort with the lighting, sounds, or seats of the theater environment (40%).

A majority (70%) of participants also "liked" or "liked a great deal" their post-show sound walk activity. Most students (60%) liked listening to sounds of nature during the audio recording of the lower pond and during their walk by the upper pond; another 30% liked the periods of silence during which they listened for sounds.

Half or less of the visually impaired students felt that the theater show and sound walk experiences increased their interest "somewhat" or "a lot" in four different soundscape topics. Students reported that their experiences increased their interest "somewhat" or "a lot" in the importance of soundscape ecology (50%), in soundscape ecology (50%), in methods and tools of soundscape ecology (40%), and how to understand spectrograms (30%). Increased interest in the topics was significantly and highly correlated with appeal of the theater show but not with appeal of the sound walk activity.

Key Findings: Learning

A majority of visually impaired students felt that they either learned "a lot" or "some" from the *Global Soundscapes* interactive theater show (70%) and their sound walk activity (60%). Perceived learning ratings were not correlated with appeal ratings, but perceived learning from the sound walk was statistically correlated with increased interest in the topics of soundscape ecology and methods and tools of soundscape ecology.

From the theater show, students felt they learned about sounds in different places from different sources, learned the scientific categories of sounds, and learned about sound measurement. From the sound walk activity, students reported learning about the scientific categories of sounds and the sources of sounds around them.

After their experience, all of the students were able to cite correct examples of sounds in all three sound categories of *anthrophony*, *biophony*, and *geophony*. One-fifth of students could provide the scientists' definition of *soundscape* as all sounds in a place.

In analyzing soundscapes, ecologists look for categories of sound, sound frequencies and amplitudes, changes over time, and differences by location. **In analyzing their neighborhood soundscapes, 40% of students proposed analytical questions about changes, differences, or explanations about soundscape sounds; 30% asked about methodology of sound recording; and 30% were unable to answer this question successfully.**

Students did not recall a main message of the theater show that collecting and studying soundscapes is important to help ecologists assess the health and biodiversity of an ecosystem. Only one student (10%) suggested that soundscapes helped one to *learn about an environment*. Almost one-third (30%) repeated the show message that soundscapes help you hear things that you cannot see, and 20% felt that soundscapes were important to experience sounds or nature.

Key Findings: Future Behavior

When asked how they might listen to the world in a new or different way after their experience at the EcoTarium, half of the students felt that they would listen more closely, listen by recording, or listen to new places; and the other half thought that they would not change how they listened to the world.

Students reported that their experiences made them feel "very" or "somewhat" likely to tell others what they learned about soundscapes (80%) and likely to record their own soundscapes (50%).

The ten students from Perkins School for the Blind presented a challenging audience for the two EcoTarium presenters of the interactive *Global Soundscapes* theater show and subsequent sound walk activity. The visiting students not only had visual impairments but possibly other issues limiting their functioning in the field trip setting. Nonetheless, findings about engagement, appeal, interest, learning and future behavior for the 10 Perkins teens did not differ much from the reactions of 33 sighted low-income minority 5th graders who participated in a similar Soundscape field trip to the EcoTarium one year earlier.

Although we have a very small sample of visually impaired students from which to generalize, we can make a few observations and recommendations for future presentations to visually impaired audiences:

- Prior to their theater and sound walk experiences, alleviate some anxiety by explaining what to expect in terms of environments including the darkness of the theater, the potential loudness of sounds, and the uneveness of the outside walk.
- Representing sounds via a visual spectrogram is a central component of the theater show. Consider providing staff and/or sighted guides with 3D printouts of the tuning fork sound for review during school or during the bus trip, so that visually impaired students can become familiar with what a spectrogram is and its main features prior to their theater experience.
- Do not assume that visually impaired students have the same curriculum experiences and/or familiarity with the world as sighted students. For example, visually impaired students could not identify the rainforest by its sounds or identify a monkey sound.
- Repeat and reemphasize the main project messages that a soundscape is all the sounds in a specific place and that soundscapes are important to help scientists understand the health and biodiversity of a place.
- Consider that the comparison of time periods (in Costa Rica) and comparison of two locations (in Hawaii) may require playing the comparative soundscapes more than one time in order for visually impaired students to focus in on differences that are more obvious for the sighted students who can also compare visually displayed spectrograms.

INTRODUCTION

Supported by the National Science Foundation, the *Global Soundscapes! Big Data, Big Screens, Open Ears* project presents the science of sound and the new science of soundscape ecology through a variety of informal learning experiences. "Soundscape ecology is an interdisciplinary science that studies how humans relate to place through sound and how humans influence the environment through the alteration of natural sound composition."[1]

Using real-time observations and a post-experience questionnaire, Multimedia Research, an independent evaluation firm, implemented a summative evaluation at Worcester's Ecotarium[2] to assess the influence on visually impaired teenagers of a 45-minute interactive, sound-based, giant-screen theater experience followed by one hour of a "sound walk" activity. The general goals for the evaluation were to assess student engagement, appeal and interest; their knowledge of soundscape ecology; and their potential future behavior related to soundscape ecology.

METHOD

Participants

Twelve teens from Perkins School for the Blind[3] in Watertown, MA, attended the field trip to the EcoTarium. Two of the twelve participated in a summer Soundscape Ecology camp and thus are not included in the final analysis group of ten students. The ten visually impaired students included 6 boys and 4 girls, ranging in age from 14 to 18, with a mean age of 16 years. Some students have some residual vision, whether it is light perception, color perception, or form perception. Perkins' staff described some students as having special needs besides visual impairment, possibly including autism, light or sound sensitivities, learning disabilities, or emotional disorders. The students were accompanied by seven adults as sighted guides including Perkins staff and EcoTarium volunteers.

Procedure and Materials

At the EcoTarium, students experienced 45 minutes of an educator-led participatory giant screen show in the planetarium theater followed by one hour of a "sound walk" listening activity. On the first two days after experiencing the theater show and activity, all students completed an accessible online questionnaire via surveymonkey.com.

[1] http://www.nsf.gov/awardsearch/showAward?AWD_ID=1323615&HistoricalAwards=false

[2] www.ecotarium.org

[3] www.perkins.org.

Theater experience. Alden Digital Planetarium at the EcoTarium features surround sound and digital technology projected onto a 40' dome to offer a 360-degree multisensory experience. The theater show[4] *Global Soundscapes: Mission to Record the Earth* follows three soundscape ecology teams in Costa Rica's rainforest, Hawaii's coral reefs, and Mongolia's vast grasslands on their mission to record the sounds of the earth. The interactive show is hosted by a female live presenter who is supported by surround sounds, giant screen images and videos, and physical props. Joined in the video by a pre-programmed female computer voice, the live presenter guides the audience through four levels of basic training in the science of sound and soundscape ecology using thought-provoking questions, explanations, and audience activity.

Prior to this 2018 evaluation, the theater show has undergone formative evaluations with both sighted students and visually impaired students as well as a summative evaluation with younger sighted students.[5] The original theater experience for sighted students has been adjusted further for visually impaired students, focusing on experiences of listening rather than seeing, as follows:

- The presenter's vocabulary changed from "seeing" to "listening."
- Interactive activities were refocused on what the audience can hear and increased kinesthetic in-seat participation.
- In deference to sensitive ears, the presenter informed the audience in advance of the hearing range demonstration that the tone generator's sound is irritating but would be played for only a short while.

The major content of the adapted show is outlined and illustrated in the results section (p. 4-7). An evaluator observed student engagement during the show.

Sound walk experience. The *Global Soundscapes* project provides a large choice of outreach activities in an educators' guide entitled Your Ecosystems Listening Labs (YELL).[6] After their theater experience, students participated in a one-hour post-show activity focused on the outdoor sound walk adapted from Activity #7 in the YELL guide. The goal of the sound walk activity is to learn to listen quietly to a soundscape, categorize sounds, and compare soundscapes from different locations.

Prior to this 2018 evaluation, the sound walk has undergone formative evaluations with both sighted students and visually impaired students as well as a summative evaluation with sighted students.[5] The original sound experience for sighted students has been adjusted further for visually impaired students, retaining a focus on listening but shortening the physical walk outdoors, as follows:

- The sighted sound walk involved visits to both the lower and upper ponds of the EcoTarium. The experience for visually impaired students included listening to an audiotape of lower pond sounds and a physical visit to the upper pond.

[4] Trailer for Global Soundscapes available at https://vimeo.com/182787882. More information at soundscapeshow.com.
[5] Summative evaluation with sighted students available at www.informalscience.org/sites/default/files/GlobalSoundscapesSummativeEvaluation_2017_0.pdf
[6] YELL = Your Ecosystem Listening Labs. For instructor and student guides of all YELLs, visit https://www.purdue.edu/fnr/ilisten/educators/

- During the sighted sound walk, students kept a written tally of sounds and their categories. The adaptation for visually impaired students was to raise hands when they heard a certain category of sound.

An evaluator observed implementation of the activity. Details of the sound walk activity are presented in the results section (p. 8-9).

Post-questionnaire. An online screen-reader accessible 15-minute questionnaire was developed based on the full set of planned objectives for the interactive theater show and the sound walk activity. The questionnaire included both open-ended and closed-ended questions and repeated questions used in a previous summative evaluation at the EcoTarium with sighted students.[5] The questionnaire was answered during the Perkins' students' science class in the two days after the EcoTarium visit and focused on assessing three areas of planned outcomes outlined below:

1) Engagement, appeal, and interest:
   a) Engagement in soundscape ecology concepts and methods supported by student interactivity and participation
   b) Interest in soundscape ecology concepts and methods triggered through immersive listening experiences

2) Knowledge about soundscape ecology:
   a) Perceived learning about soundscape ecology
   b) Knowledge of soundscape fundamentals including definitions of biophony, geophony, anthrophony, and soundscape
   c) Understanding of soundscape ecology analytical approaches; e.g., looking for patterns, changes over time, differences by location
   d) Knowledge of the importance of soundscape ecology to assess health of an ecosystem

3) Potential behavior:
   a) Likelihood of doing a variety of post-visit activities related to soundscape ecology

Data Analysis

Quantitative rating responses are presented in frequency bar charts. Non-directional non-parametric statistical comparisons were implemented; non-parametric statistics are used when a sample size is small and data are in ordinal or nominal scales. Statistically significant findings at $p \leq .05$ are reported, meaning that in 5 of 100 cases the result would appear by chance or that there is a 95% probability that the effect truly exists. For easier reading, footnotes present a definition of a statistic when first used in the report and also present the statistical test results.

Qualitative data from open-ended survey questions were sorted into categories pertaining to the main messages of the theater show and sound walk activity. For easier reading, some illustrative quotations in *italics* from participant responses have been edited slightly.

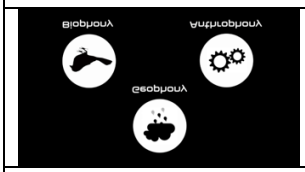
FINDINGS: ENGAGEMENT, APPEAL AND INTEREST

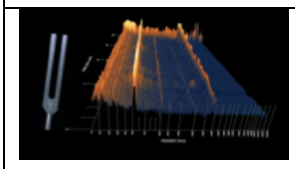
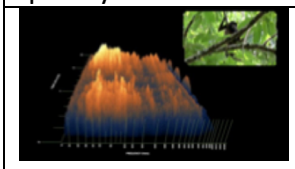
Engagement with the Theater Experience

During the 45-minute theater show, the audience was observed for behaviors indicating engagement or boredom. ***Throughout the show, students were observed to be engaged with the audio sounds and audience interactivity, and about half were verbally responsive to the presenter's questions.*** The left column of Table 1 illustrates and outlines the major content of the *Global Soundscapes* interactive theater show and describes student responsiveness during the show in the right column. Note that several times in the show the audience is asked to listen to a soundscape while the screen is dark.

Table 1. Engagement with *Global Soundscapes* interactive theater show

<table>
<tr><td colspan="2"> 
Preshow warmup cycling through eight soundscapes with on-screen visual captions of what do you hear, where are we</td></tr>
<tr><td> 

Live female presenter introduces interactive aspect of show, warms up audience, encourages out loud participation with initial audience activity: Think about your favorite park. Tell me what sounds are in that park."</td><td>A majority of students responded to the presenter's question, giving such answers as birds, basketball, dogs, kids having fun.</td></tr>
<tr><td colspan="2">Computer voice introduces Level 1 mission training: Welcome. A team of scientists is on a mission. Today you will join this team on the mission, travel around the world, help scientists analyze sound, and along the way, make some discoveries of your own.
Presenter introduces soundscape definition, why soundscape recording is important, and that audience will be listening and observing with their ears.</td></tr>
<tr><td>Dark screen listening experience of beach soundscape. Presenter asks what they heard and where sounds came from. Presenter defines soundscape as combination of all different sounds in a specific location.</td><td>Students told what they heard (lightning, thunder, wind, water, seagulls, dog, children) and identified a beach setting.</td></tr>
<tr><td> 
Presenter defines the three sound categories: biophony, geophony, anthrophony.</td><td>Students responded to questions about the three categories with examples from the prior beach audio.</td></tr>
<tr><td colspan="2">Computer voice reviews level 1: Congratulations! You have completed basic training level 1. You have learned that a soundscape includes all the biophony, geophony, and anthrophony sounds recorded in a place. Proceed to Level 2.</td></tr>
</table>

Dark screen listening experience of rainforest soundscape. Presenter asks for guess about location of soundscape.	Students could not identify the audio as rainforest. One guesses *woods;* another responds that it *sounds scary.* Presenter notes the *grumpy* howler monkey in the rainforest setting, and the audience responds with laughter and clapping.
 Video and narrative explanation of soundscape ecology team activity in Costa Rican rainforest.	Students were attentive.
 Presenter uses demonstration with cymbal prop and cymbal video to show how sounds are made by vibrations.	Students were attentive.
 Presenter shows how sounds are made by vibrations using audience participatory activity of raspberry blowing. Video shows multiple faces making raspberry sounds.	Students laughed and blew raspberry noises, commenting that it felt *weird.*
Presenter demonstrates how sounds change in frequency and amplitude, using participatory vocal cord humming at high and low frequencies and amplitudes.	Students laughed and hummed high and low. They could feel the vibrations, noting that it felt *weird.*
 Intro of 3D spectrogram tool to study sound. Presenter shows tuning fork and encourages kinesthetic involvement of audience moving their arms from left to right to indicate where low and high frequency sounds are represented on a visual spectrogram.	Students were familiar with tuning forks: *My doctor has one of those.* Most students followed the presenter's instructions about pointing to the left and moving to the right to reflect frequency changes in the tuning fork spectrogram.
 Presenter plays howler monkey spectrogram, describes the visual and asks questions to reinforce frequency and amplitude terminology and how sounds change over time.	The howler monkey sound was new to most students, but responses to the presenter's questions indicate that some understood that the sound was *low* in pitch and *loud* in volume. When asked to produce the monkey sound themselves, most participated.
 Rainforest video and narration presents analytical research questions of science team.	Students were attentive.

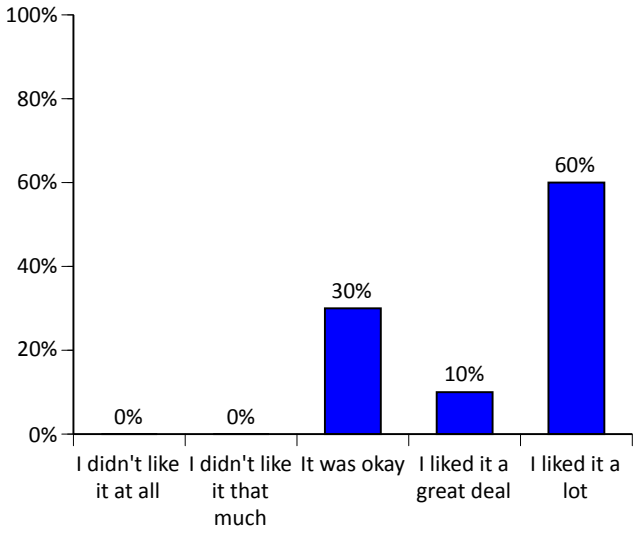
 Audience listens to rainforest sounds in 2008 and 2015. Presenter asks questions to compare sound-scapes in the two time periods and emphasizes that ecologists study sound to assess health of ecosystem and ecosystem changes over time.	Students were quiet in response to the presenter's efforts to elicit observations about differences between the two soundscapes. Students did note that frogs made more noise in *2008* com-pared with 2015, which is one critical point of the activity.
Presenter summarizes level 2 soundscape ecology training and calls up coral reef science team, to move to level 3.	
 Video and explanation of science team activity at Hawaiian coral reef.	Students were attentive.
 Audience listens to and compares soundscapes of healthy (left, reef 1) and less healthy (right, reef 2) reefs.	A few students responded to presenter's questions to describe what was heard in reef 1 and reef 2; e.g., *I think they both sounded the same. One was higher and one was lower.* Reef 2 *was quieter.* Students noted that the snapping shrimp, identified by the presenter, *sounded like fire.*
Presenter notes completion of level 3 training and calls up Mongolian science team to move to level 4.	
 Video and narrative explanation of soundscape ecology team activity in Mongolia.	Students were attentive. One student notes hearing a foreign language in the background sound.
 Traditional Mongolian throat singing demonstrated in audio and video and then tried out by audience under presenter's diretions.	Most students participated, but quietly, when asked to try the throat singing.
Mongolian Tuul River nightscape video plays and presenter notes sound frequency of bats, invisible to our human ears. Presenter discusses bats.	Students attentive. They noted hearing horses but could not guess that bats made the highest frequency noise.
Presenter uses sound generator to run a human hearing test in which audience members raise their hands when they begin to hear a sound.	The students raised their hands before the adults and laughed when the presenter pointed out that the older audience could not hear sounds at the high frequencies that they could.

Presenter shows closing slide of project websites and then asks the audience to voice their own soundscape.	Students participate quietly in making their soundscape and clap at the end of the show. One student gets up to dance to the closing scene of throat singing.
Presenter reminds audience that they have completed the basic soundscape ecology training and explains that they will continue advanced training next on a sound walk.	

Appeal of the Theater Show

Figure 1 indicates how much the ten visually impaired students liked the *Global Soundscapes* theater experience: ***70% either liked the show a lot (60%) or liked the show a great deal (10%).***

Figure 1. Appeal of Theater Experience (N = 10)



The theater audience most liked hearing different sounds (60%). For example:

I liked all the different sounds.
I liked the sounds of the whale.
I liked the throat singing.
I liked how they were doing all the high and low pitches.

Four students noted a variety of other engaging components of the theater show:

Because it showed different places and how they measure the sounds in those places.
I liked that the theater experience was interactive and I also liked all the technology that was involved.
I liked how it would switch between segments.
I loved learning the new vocabulary.

When asked what they did not like about the theater show, 40% reported liking everything. Some students were uncomfortable with the theater environment (40%); for example:

I did not like the seats.
I felt that the different lighting changes and colors gave me a headache.
I did not like how dark it was because it felt a little scary.
I did not like how dark it was. I couldn't see anything on the screen but the volume was perfect.

A Perkins faculty member noted in response to the above three comments: *I think that for those students with some vision, their vision can be a distraction. They focus on what they can't see as opposed to what they can hear.*

Two more students did not like the loud or high-pitched sounds:

The high pitched squeak.
I did not like the loud beep.

Engagement with the Sound Walk Activity

The EcoTarium's post-show activity was implemented by a second female presenter. The one-hour activity began inside by listening to an audio recording of the sounds of EcoTarium's lower pond and then moved outside for on a physical walk to listen to the upper pond soundscape. The goal of this activity is to learn to listen quietly to a soundscape, categorize sounds, and compare soundscapes from different locations. During the activity, about half of the students responded verbally to the presenter's queries and the other students were quiet but attentive.

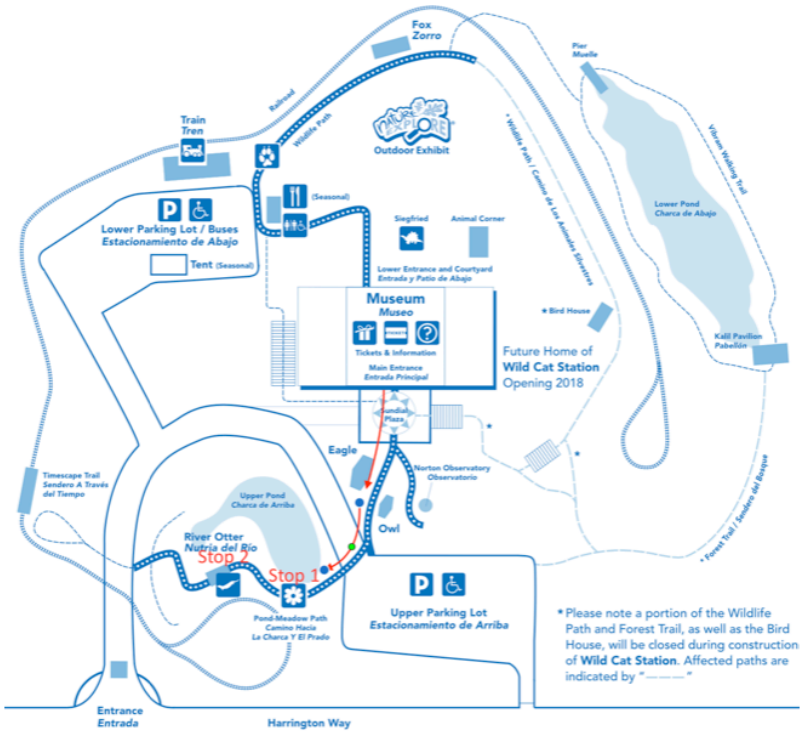
The first half-hour activity occurred in the planetarium with a review of examples of the three categories of sound: biophony, geophony and anthrophony. The presenter explained how a soundscape of the EcoTarium's lower pond was recorded and that the students would listen to the recording three times, listening for one category of sound each time. With each repetition, the presenter gave students the choice of which category of sound on which they were to focus their listening. Students were to raise their hand if they heard the announced category:

- Geophony was the students' first choice, which the presenter defined as sounds of the earth. One student raised a hand during the listening period, and after the recording finished, others reported not hearing any geophony sounds. The lower pond soundscape included the sound of rain on the pond water but that apparently was difficult to distinguish from other sounds.
- Anthrophony was the students' second choice, which the presenter defined as sounds that humans make or sounds of human machines. Four students raised their hands during the listening period. Students reported hearing sounds of *people talking*, *an ambulance,* and *a truck or construction*, which the presenter identified as a train going by. The presenter had students identify the amplitude and frequency of the sounds as high or low.
- Biophony was the last sound to focus on, which the presenter defined as sounds of life. Six students raised their hands and reported hearing *birds* and humans *walking*.[7]

After playing the lower pond recording three times with a focus on each of the three sound categories, the presenter again defined a soundscape as a collection of sounds in one place and described the location of the upper pond, which the group would visit, as a place close to a main road and close to a high school and preschool. When the presenter asked students to predict the sounds that they would hear at upper pond, they suggested sounds of a *school bell* and *train*. Students predicted *anthrophony* sounds because they were *going to be outdoors and closer to the road.*

In the subsequent half-hour, the group walked out to EcoTarium's upper pond, stopping at two points to listen quietly each time for two minutes and then sharing observations on the categories of sounds heard. The red on the following map shows the sound walk path.

[7] Although "humans walking" are sounds of life, scientists would classify this sound as anthrophony. Anthrophony category includes any sounds produced by humans as well as those produced by human built machines. https://www.ilisten.org/soundscape-composition



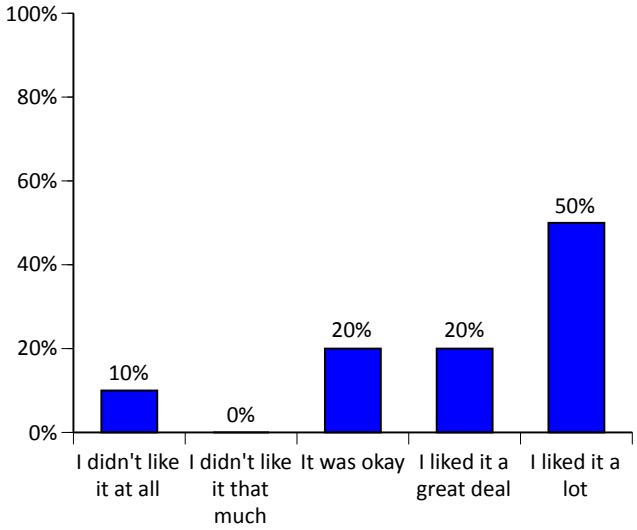
- At the first stop on the walk near the pond and a fountain, the presenter asked students to listen quietly for two minutes and then asked if they heard biophony: answers included *birds, motorcycle, water*. The presenter asked questions of students to clarify that motorcycle fits into the anthrophony category and water fits into the geophony category. The presenter then described the water sound as coming from a manmade fountain and asked what category the fountain motor would be in; a student responded *anthrophony*.
- At the second stop, near the otter exhibit and closer to the fountain, the presenter divided the students into three groups, with each group told to listen for a different category of sound. The Geophony group reported hearing *louder water*, and the presenter drew out the description of *high amplitude*. The Anthrophony group identified *people talking* (at the otter exhibit) and *footsteps on the bridge* (from gravel underfoot). The Biophony group observed *a family talking* and *wind*; the presenter corrected the categorization of these examples and described that there were insects present although they did not make much noise. In a side conversation, one participant noted hearing a bullfrog.

The presenter reminded students that their prediction for sounds at the upper pond was for more anthrophony but students had not reported hearing the cars on the main road close to the pond. In closing, the presenter asked students if they would have a different experience if they came to the ponds over a whole week or a whole month. Students agreed the soundscape experience would be different.

Appeal of the Sound Walk Activity

Figure 2 indicates how much the visually impaired students liked their sound walk activity: ***70% either liked the sound walk activity a lot (50%) or liked it a great deal (20%).***

Figure 2. Appeal of sound walk activity (N = 10)



The majority of students reported that they most liked listening to sounds of nature (60%). Another 30% liked the periods of silence during which they listened for sounds, and one student noted that the activity was fun. For example:

I liked hearing nature.
I liked getting the opportunity to listen to all the different sounds.
I liked the sound of the train.
I liked hearing a bullfrog.
I liked when we were silent for 2 minutes.
I liked how we were sectioned off into different groups and how we got to be silent and listen to all the noises around us. I liked that it was interactive.
I liked how quiet it was at times and that there was no talking. It was just silent.
I liked it because it was fun.

When asked what they did not like, 70% of students responded that they liked everything about the sound walk. *The remaining students commented as follows:*

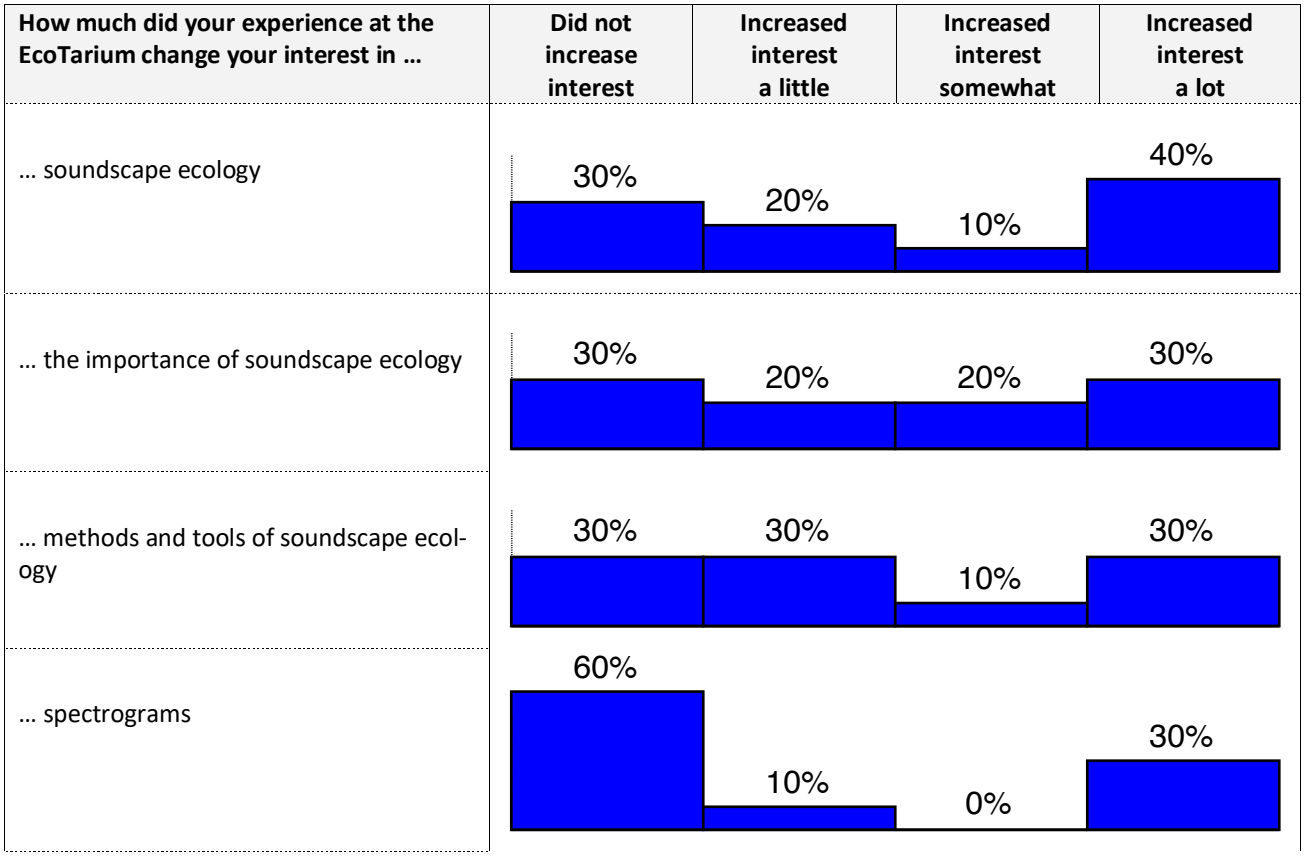
I did not like the sound walk because I was tired.
I didn't like the man-made pond.
It was not as noisy as I thought it would be.

Change in Interest in Program Topics

On a four-point scale, students were asked to indicate how much their experience at the EcoTarium changed their interest in four soundscape related topics: ***50% to 30% of the visually impaired felt their interest increased "a lot" or "somewhat" in the soundscape topics.*** Figure 3 below shows that:

- 50% of students rated that their experience with the theater show and sound walk activity increased their interest a lot or somewhat in *soundscape ecology* and in *the importance of soundscape ecology*;
- 40% reported a lot or some increased interest in *methods and tools of soundscape ecology*;
- 30% felt that their interest in *spectrograms* increased a lot or some. Since the spectrograms are mainly a visual component of the experience, one might expect little to no change in interest for visually impaired students.

Figure 3. Impact of EcoTarium field trip experience on interest in soundscape topics (N = 10)



Appeal ratings of the theater show were significantly and highly correlated with Increased interest in three of the four topics: soundscape ecology,[8] the importance of soundscape ecology[9] and spectrograms.[10] Appeal ratings of the sound walk activity were not correlated with increased interest in any of the topics.

[8] $r_s(8) = 0.70$, $p < 0.02$. The two-tailed Spearman rank-order correlation coefficient, r_s , assesses the strength of association between two ranked variables, in this case "topic interest" and "appeal" ratings.
[9] $r_s(8) = 0.78$, $p < 0.008$.
[10] $r_s(8) = 0.63$, $p < 0.05$.

FINDINGS: KNOWLEDGE OF SOUNDSCAPES

Perceived Learning from Experiences of the Theater Show and Sound Walk

Figure 4 below shows that ***70% of the visually impaired students felt they either learned a lot (50%) or some (20%) from their theater experience.*** Figure 5 indicates that ***60% of students either learned a lot (50%) or some (10%) from their sound walk activity.*** Those who felt they learned from the theater experience also reported a similar level of learning from the sound walk activity.[11] Perceived learning from the theater show or sound walk was not statistically significantly correlated with the respective appeal ratings of these experiences. However, perceived learning from the sound walk was statistically correlated with post-experience interest in soundscape ecology[12] and interest in methods and tools of soundscape ecology.[13]

Figure 4. Perceived learning from theater experience

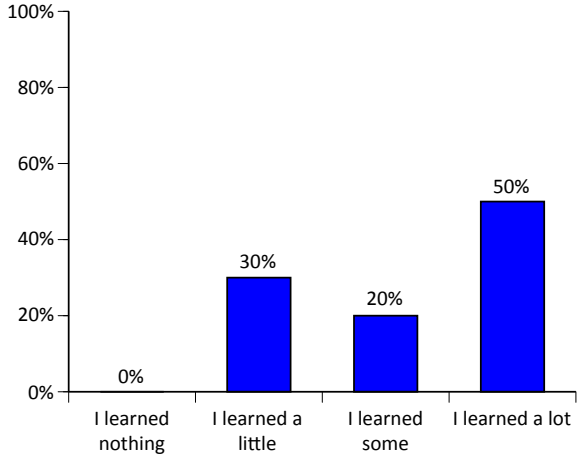
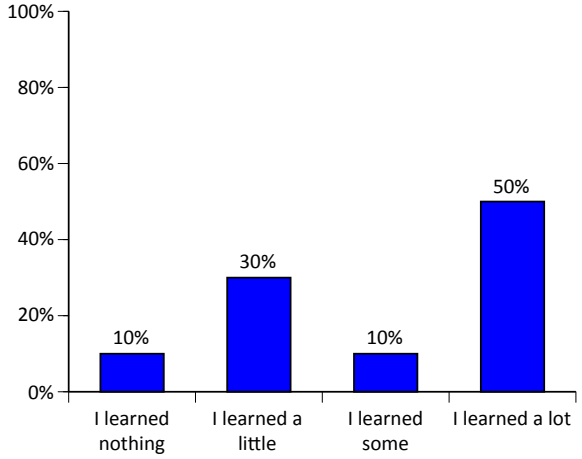


Figure 5. Perceived learning from sound walk



From the theater show, students felt they learned about sounds in different places from different sources, learned the scientific categories of sounds, and learned about sound measurement.

There are a ton of sounds around the world.
I did not know that coral reefs made sound.
I learned how people do the throat singing.
I learned about different kinds of sounds.
Different animals made different low and high pitches.
I learned how there are different sounds and frequencies.
I learned that there are 3 different categories of sounds.
I learned some new vocabulary that I did not know before. I got to learn about the different kinds of technology that scientists use to do these soundscapes.
How people measure sounds and that even a coral reef also has sounds.
I learned how people can measure sound.

[11] $r_s(8) = 0.96$, $p < 0.00001$.
[12] $r_s(8) = 0.76$, $p < 0.01$.
[13] $r_s(8) = 0.66$, $p < 0.04$.

From the sound walk activity, students reported more focus on learning the scientific categories of sounds and the sources of sounds around them; for example:

I learned about the different categories of sound.
I got to actively learn about the 3 different categories of sounds.
I learned about the 3 different categories sound can be put into.
The different categories you can put sounds into.
I didn't know about the different ways that sound could be categorized.
People can make sounds. Anthrophony sounds.
I learned that ponds can make noise. I learned how loud a bull frog can be.
I learned how bull frogs make noise and how they sound.
I never really thought about listening to my environment to figure out what is around me.
I did not feel that I learned anything.

Terminology

Soundscape. As defined in the theater show and the sound walk, a soundscape is the combination of all the different sounds in a specific location. **One-fifth (20%) of students could provide a definition of the term soundscape that was close to the scientists' definition.** The definitions of soundscape given by the visually impaired students included the following categories:

- 20% noted the idea of place, environment, or location:
  A soundscape is listening to an environment and then putting the sounds I hear into 3 different categories (biophony, anthrophony and geophony).
  A soundscape is a place.

- 30% focused on soundscapes as recordings of sounds but did not note a focus on location:
  A soundscape is recordings.
  A soundscape is a recording in any format of any type of sound.
  It is a tool used to measure sound.

- 20% defined soundscapes as a description of sounds:
  A soundscape is how scientists identify what sounds are.
  They can be loud and quiet at the same time.

- 20% described soundscapes simply as sounds heard:
  A soundscape is something I hear.
  Listening to different sounds.

- 10% may have mixed the term soundscape with the term spectrogram:
  A soundscape is something people make.

Biophony, geophony, anthrophony. The questionnaire asked for an example of each type of sound that students might hear in their own neighborhood. **All students (100%) could provide appropriate examples of biophony, anthrophony and geophony sounds,** as follows:

- Examples of Biophony: 60% *dogs*, 20% *birds*, 20% *cats*
- Examples of Anthrophony: 70% *cars*, 20% people sounds (*building houses, crossing streets*), 10% *iPad sounds*
- Examples of Geophony: 70% *wind*, 20% *thunder*, 10% *snow falling*.

Analytical approaches

In analyzing soundscapes, ecologists look for categories of sound, sound frequencies and amplitudes, changes over time, and differences by location. To examine student understanding of analytical approaches presented in their *Global Soundscapes* experience, the questionnaire asked students to suggest one question that a soundscape ecologist might ask about soundscapes that the students imagined recording several times in different places around their neighborhood. **Two-fifths (40%) of students proposed analytical questions about changes, differences, or explanations about soundscape sounds. Another 30% asked about methodology of sound recording.**

- 40% addressed differences, changes or explanations:
  Is it always this active in your neighborhood?
  What are the differences and the similarities between the sounds?
  Why are there so many car noises?
  Why is there so much construction?

- 30% focused on methodology:
  What did you use to record these soundscapes?
  Why did you record/make this soundscape?
  How long did you record for?

- 20% wrote *I don't know.*

- 10% asked the simple identification question of *What did you hear*?

Importance of soundscapes

The visually impaired students did not recall a main message of the theater show that collecting and studying soundscapes is important in helping ecologists assess the health and biodiversity of an ecosystem. Only one student (10%) suggested that soundscapes helped one to *learn about an environment*. Almost one-third (30%) repeated the show message that soundscapes help you hear things that you cannot see; 20% felt that soundscapes were important to experience sounds or nature; and 40% responded that they did not know why it is important to collect and study soundscapes.

- 30% recalled that soundscapes are important because you can hear things that you can't see:
  Maybe you could hear animals that you thought were never there.
  Maybe you would be able to make discoveries with your ears instead of relying on your eyes.
  You can figure out what is around you.

- 20% thought soundscapes were important to experience sounds and/or nature; for example:
  So that I know what it is.
  So you can know how nature sounds.

- 10% suggested that soundscapes are important to learn about an environment:
  It can help you learn about the environment.

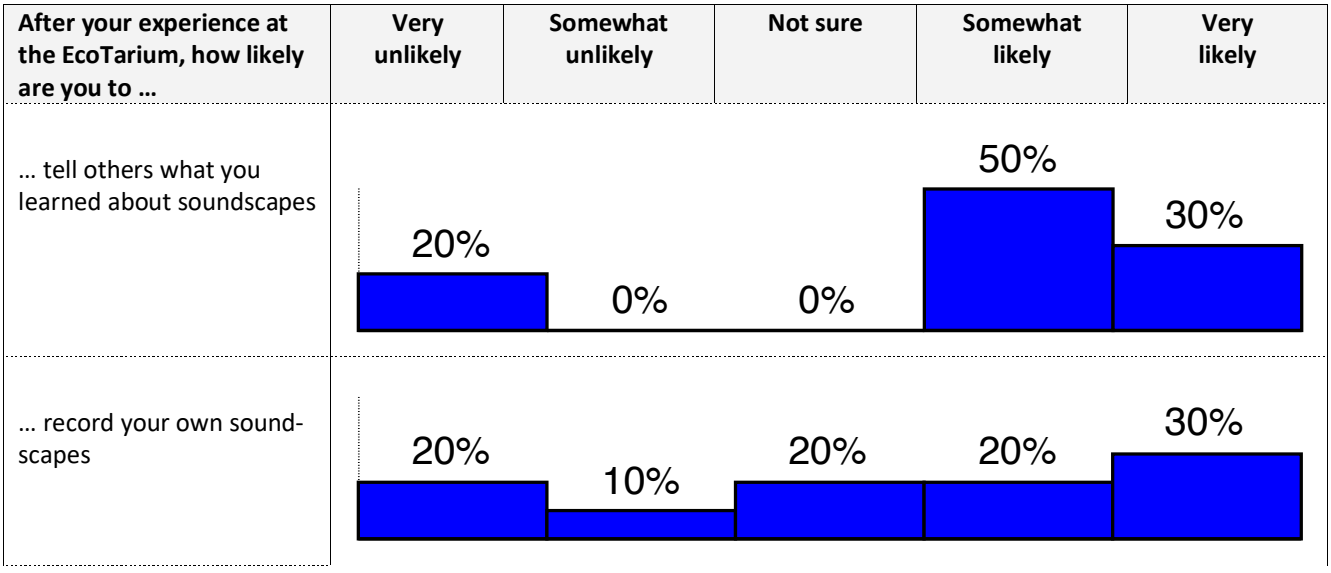
FINDINGS: FUTURE BEHAVIOR RELATED TO SOUNDSCAPE ECOLOGY

Students were asked how they might listen to the world in a new or different way after their experience at the EcoTarium. ***Half (50%) of the students felt that they would not change how they listened to the world. The other half suggested that they would listen more closely, listen by recording, or listen to new places:***

Now I know that even the smallest things have sounds, I will listen more closely.
I might listen to the world in a different way by not just listening to the earth but listening for people, animals, and any other noises the world makes.
Record the sounds around me.
With my iPad.
I would travel to listen in new destinations.

On a five-point scale, students rated how likely they were to do two activities after their experience at the EcoTarium. Figure 6 shows that ***a majority (80%) of students thought they were "very" or "somewhat" likely to tell others what they learned about soundscapes and 50% felt "very" or "somewhat" liked to record their own soundscapes.*** Likelihood to tell others what they learned was significantly and highly correlated with appeal ratings of the theater show[14] but not correlated with the sound walk activity.

Figure 6. Impact of *Global Soundscapes* experience on future behavior (N = 10)



[14] $r_s(8) = 0.73,\ p < 0.02$

DISCUSSION

The *Global Soundscapes* interactive theater show and subsequent sound walk activity effectively engaged and appealed to our small sample of visually impaired teenagers, and half of the participating students felt their interest increased in soundscape ecology and the importance of soundscape ecology. Exposure to the theater show and post-show sound walk increased knowledge of categories of sound but the experiences were less effective in communicating scientists' approaches to analyze soundscapes and the message that soundscapes help assess the health and biodiversity of an ecosystem. The visually impaired students also reported that following their field trip they were likely to tell others about what they learned about soundscapes, likely to record their own soundscapes, and would listen to the world in new and different ways.

The ten students from Perkins School for the Blind presented a challenging audience for the two EcoTarium presenters of the interactive *Global Soundscapes* theater show and sound walk activity. The visiting students not only had visual impairments but possibly other issues limiting their functioning in the field trip setting. Reactions from the 10 Perkins teens did not differ much from the reactions of 33 sighted low-income minority 5th graders who participated in a similar field trip to the EcoTarium one year earlier:

- With respect to engagement, appeal, and interest outcomes:
    - Students of both groups were attentive to the theater show, responsive to the presenter's questions and participation directions, and a large majority liked the experience, noting that they enjoyed hearing different sounds.
    - A large majority of both groups gave high ratings to their sound walk experience and enjoyed listening to the sounds of nature.
    - The EcoTarium experience was more effective in increasing interest in soundscape topics for the sighted students compared with the visually impaired students.
- With respect to learning outcomes:
    - All students in both groups were able to provide correct examples of sounds in all three sound categories.
    - In both groups, only one student was able to recall an intended main message of the experience that collecting and studying soundscapes is important to help ecologists assess the health and biodiversity of an ecosystem.
    - More sighted students compared with visually impaired students could provide the scientists' definition of a soundscape as all sounds in a place (40% vs. 20%), but more visually impaired teens described complex approaches to analyze a neighborhood soundscape compared with the younger sighted students (40% vs. 12%).
- With respect to future behavior:
    - Similar percentages of both student groups reported that their experience made them feel very or somewhat likely to tell others what they learned about soundscapes and to record their own soundscapes.

The Perkins' staff were also pleased with their students' experience commenting: *It was a wonderful introduction for the students to the worlds of sound and ecology* [with] *clear descriptions and attention-getting dialog. Wonderfully accessible to all!*

Although we have a very small sample of visually impaired students from which to generalize, we can make a few observations and recommendations for future presentations to visually impaired audiences:

- Prior to their theater and sound walk experiences, alleviate some anxiety by explaining what to expect in terms of environments including the darkness of the theater, the potential loudness of sounds, and the uneveness of the outside walk.
- Representing sounds via a visual spectrogram is a central component of the theater show. Consider providing staff and/or sighted guides with 3D printouts of the tuning fork sound for review during school or during the bus trip, so that visually impaired students can become familiar with what a spectrogram is and its main features prior to their theater experience.
- Do not assume that visually impaired students have the same curriculum experiences and/or familiarity with the world as sighted students. For example, this audience of visually impaired students could not identify the rainforest by its sounds or identify a monkey sound.
- Repeat and reemphasize the main project messages that a soundscape is all the sounds in a specific place and that soundscapes are important to help scientists understand the health and biodiversity of a place.
- Consider that the comparison of time periods (in Costa Rica) and comparison of two locations (in Hawaii) may require playing the comparative soundscapes more than one time in order for visually impaired students to focus in on differences that are more obvious for the sighted students who can also compare visually displayed spectrograms.