Curriculum Units by Fellows of the Yale-New Haven Teachers Institute
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Physics of Sound: How We Hear Sounds

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Introduction

"The best and most beautiful thing in life cannot be seen, not touched, but are felt in the heart." (Hurwitz, pg 3) This quote by Hellen Keller demonstrates the keen sense of her world and the world around her, which most of us take for granted. We as people are often preoccupied with our own lives and responsibilities to recognize the simple beauty in things we see and hear in our everyday lives.

Hearing is perhaps the one sense we take for granted the most. We often do not realize the different sounds that flood our ears on minute-to-minute bases. Also, the complex concept of sound and hearing is usually taken for granted. We simply assume that our ears and brains are doing their jobs to allow us to hear, and we do not give it a second thought.

This unit on hearing sounds is targeted for second grade students. I teach second grade at Bishop Woods Elementary School. My classroom is made up of a diverse group of students. A majority of the students are African American and Hispanic. Also I have four special education students mainstreamed into my classroom. Included among my students is a hearing impaired child. Academically my classroom is also extremely diverse. I have several students performing on or above grade level, while a significant number of children are e performing below grade level.

The purpose of this unit is to introduce students to the physics of hearing sound. Students will gain a basic understanding of how sounds are produced, as well as the mechanics of why and how we hear. Students will also be given the opportunity to explore different sounds, and gain an appreciation for their sense of hearing. Students will also gain insight into the life of a hearing impaired person, through demonstrations and experiments which deal with the loss of hearing. Hellen Keller will be the main focus during the discussion and investigation of hearing impaired people. Throughout the unit students will be creating a hearing vocabulary chart based on the new words and phrases learned throughout the unit. The unit focuses on four sections. Section one will focus on hearing and how our ear works. The second section will focus on hearing impairments and the life of Hellen Keller. Section three will delve into the mechanics of sound, such as sound waves, pitch, and loudness. The final section will focus on speed of sound and direction of sound.

Curriculum Standards

This unit on sound is an integrated unit, which covers many of the Language Arts and Science standards required by the State of Connecticut. Through the integration of the book *Helen Keller Courage in the Dark* by Johanna Hurwitz, many language arts standards are being addressed.

Content Standard 1: Reading and Responding:

Students will be able to describe the text by giving an initial reaction to the text and describing its general content and purpose.

Content Standard 1.1:

Students in K-4 will describe the thoughts, opinions and questions that arise as they read, view or listen to a text and use information from the text to summarize the content. Throughout this unit students will meet this standard through response journals, after listening to the text of Helen Keller.

Another subset of Content Standard 1 states that students will interpret the text by using prior knowledge and experiences. Students in K-4 will use what they know to identify or infer important characters, settings, themes, events, ideas, relationships or details within a work. An example from the unit of this standard is allowing the students to role-play Helen Keller's daily tasks using what they have learned from the text.

The unit lends it self to fulfilling many of the science goals and standards for students in grade K-4. According to the Connecticut Department of Education, " By the end of grade twelve in science, students will know the basic concepts of biology, chemistry, physics, and earth…and will be able to apply scientific skills, processes and methods of inquiry and real world settings." This unit is in alignment with several content standards for students in grades K-4.

Content Standard 1: The Nature of Science

Students will experience an inquiry-based learning environment in which they are free to ask questions, seek information and validate explanations in thoughtful and creative ways.

Content standard 1.2:

Students will raise questions about their surroundings and seek answers by making careful observations and trying things out.

Content Standard 1.4:

Students will describe things as accurately as possible, because careful, complete observations enable people to compare their observations with those of others.

Content standard 1.5:

Students will use their senses to make observations about the natural world and discuss findings.

Content Standard 1.7:

Students will design and conduct simple experiments, keep accurate records of their findings, and communicate their findings.

(State of Connecticut, 6/25/03)

Unit Outline

1. How our ear works

2. Hearing Impairment: The Life of Helen Keller

3. Mechanics of Sound

4. Speed of Sound and Distance

Unit Objectives

Often in a student's school day so much emphasis is given to reading and math, that science and social studies are neglected. This unit will integrate many disciplines, such as language arts, math and of course science. An inquiry approach to teaching and learning will be evident in many lessons throughout the unit. Students will have opportunities to explore different dimensions of sound, while also gaining an appreciation for one of our senses that we often take for granted. Students will be given the opportunity discover how and why we hear, and what life would be like if we did not have this ability. The unit objectives are listed below.

1. Students will identify, label, and define the parts of the ear.

2. Students will read *Helen Keller Courage in the Dark* by Johanna Hurwitz and respond critically to the text.

3. Students will investigate different mechanisms of sound and how sounds differ.

4. Students will work in cooperative groups to create a game about a topic being discussed.

Due to the age of students this unit will investigate sound in its simplest form. Students will be responsible for completing response journals after each lesson. Each journal entry will be led by an open-ended question for students to reflect upon and respond to. At the end of the unit students will be responsible for their culminating activity, which will be to produce a game about a concept learned throughout the unit.

Vocabulary List

Outer Ear Braille

Inner Ear vibrations

Middle ear pitch

Pinna frequency

Acoustic nerve Hertz

Eardrum sound wave

Ossicles amplitude

Cochlea period

Organ of Corti decibels

How the Ear Works

Our ears are more than a place to hold up our glasses or display fashionable earrings. The ear is a complex part of the body made up of an intricate system of bones and hair follicles. One of the smallest parts of our body is responsible for such a large part of our survival in the everyday world. The ear is made up of five sections: the outer ear, the middle ear, the inner ear, the acoustic nerve, and the brain's auditory processing center. To begin, the outer ear is the part of the ear that is visible on our heads, which is called the pinna. The pinna is responsible for collecting the sound vibrations. When a sound reaches your ear the first place it travels to is your eardrum. Before a sound vibration reaches the eardrum it travels through a thin canal, which is covered with tiny hairs and wax. The hair and wax in the ear canal help to keep out foreign debris such as dirt and bugs. The eardrum is the beginning of the middle. The eardrum is made up of a translucent fiber. Connected to the eardrum are three tine bones called the ossicles. When sound waves reach the eardrum the ossicles vibrate which produce mechanical sound waves. These waves are transmitted to the inner ear. The inner ear is comprised on many different parts, however the main vessel in the inner ear is the cochlea. The cochlea is the size of a pea and resembles the shape of a snail. The cochlea holds the Organ of Corti, which is the sensory receptor of the ear. Inside the organ of corti are tiny hairs, which act as the nerve receptors of hearing. The nerve receptors send messages to the brain about the sound such as the loudness and pitch.

(http://faculty.washington.edu/chudler/bigear.html, 6/25/03; please see Bibliography at the end of this unit)

Hearing Impairments

There are several different types of hearing impairments. Some are caused by old age, while others are hereditary or caused at birth. Whatever the cause of the hearing impairment, living with this disability is a life altering challenge. As stated before, there is not one known cause of deafness or hearing loss. There are a few basic types of hearing loss. One is conductive hearing loss. This happens when there is a problem with the outer or middle ear. Most people with conductive hearing loss have mild and temporary loss, which can be medically treated. The cause of conductive hearing loss usually occurs at birth in the form of malformed parts of the ear. At times there may be tiny holes in the eardrum, or wax build up in the ear canal. Acoustic Neurinoma is an example of this type of hearing loss. It is a benign tumor, which forms on the nerves in the inner ear. This tumor causes the vibrations from the inner ear not to be transmitted to the brain therefore prevents the person from hearing sounds. Another type of hearing loss is sensory hearing loss. The cause of this type of hearing loss can be hereditary, or can be caused in the fetus, if a pregnant mother suffers from certain types of diseases. Sensory hearing loss can also be caused by severe damage to the head or by listening to or being around loud noises such as music or fireworks on a constant basis. This type of hearing loss occurs when the cochlea is not working properly. The hairs inside the cochlea have been damaged in sensory hearing loss. Often times the damage is permanent. The loss of hearing can affect one ear or both, and it will often affect the speech of a person. Mondini Syndrome is also related to the cochlea, however in this case the cochlea is not complete or abnormally shaped. Mixed hearing loss is a combination of conductive and sensory hearing loss. Neural hearing loss occurs when there is a problem with the connection from the cochlea to the brain. One condition of neural hearing loss is auditory neuropathy, in which the cochlea of the ear functions properly, however, the nerve receptors to the brain do not. As stated before, there are also severe diseases that can cause hearing loss. Perhaps the most deadly and dangerous of these diseases is Meningitis. Meningitis is a severe sickness with symptoms such as high fever and extreme fatigue. Often people suffering form Meningitis will gradually experience hearing loss, as was in the case of Helen Keller. (Nichcy Fact sheet, 6/25/03)

The Life of Helen Keller

Helen Keller was a woman who faced many obstacles in her life, but overcame them with dignity and pride. When Helen was 19 months old she became very ill. The doctors at the time did not know what the illness was. We now know today because of her symptoms, Helen was suffering from Meningitis. Although many people suffering from Meningitis die, Helen overcame and survived this terrible illness. What seemed like a gift from god turned tragic again, when Helen’s parents soon realized that their daughter was not responding to sounds as well as hands or objects flashing in her face. It was soon discovered that the illness Helen had suffered left her both deaf and blind. A person dealing with two drastic disabilities would be likely to give up and not pursue a better, more fulfilled life. This was not the case with Helen. Along with the support of her family and Anne Sullivan, a blind teacher, Helen overcame her obstacles and has become a hero to any person trying to overcome a challenge. (Hurwitz, pg 4-25)

Mechanics of Sound

The concept of sound is extremely complicated as well as technical. There are several components of sound, such as pitch, loudness, and waves. To begin we must understand that vibrations cause all sounds. When a sound is made such as a bell or a hand clapping, the vibrations from the sound bounce off surrounding particles such as air. As the waves pass through the air the particles in the air vibrate as well moving forward and backwards. A sound wave like all waves can carry energy from one place to another. There are three specific aspects of a sound wave. The first is the wavelength. This represents the length of one cycle of sound. It is the length in space of a sound. The period of a sound wave is the time taken for one wavelength to pass a certain point before a new wave begins. A longer wave period represents a lower pitch sound. The third part of a sound wave is the amplitude. The amplitude of a sound wave represents the loudness of the sound. The higher the amplitude, the louder the sound. (School for Champions/Science/Sound, 6/10/03)

Another important dimension of sound waves is their frequency. Frequency of a wave refers to how often a wave passes through a specific location. Frequency is measured by the number of complete back and forth vibrations of a particle. The frequency of a sound wave is measured in cycles per second, or Hertz.

1 Hertz = 1 vibration/second

Sound travels at 330 meters per second or 740 miles per hour.

740 mile/ hour = 330M/s x 3.3 Ft./M x 1 mile/5280 ft x 3600/hr

A sound wave will vibrate at different rates, which is the frequency of a wave. The faster an object vibrates, or higher the frequency the higher the pitch of the sound. A high pitch sound will have a high frequency, while a low pitch sound will have a low frequency. The shorter a wavelength appears the faster the object is vibrating and the frequency will be higher. If a wavelength is spread apart the slower the objects vibrating, and the frequency is lower. A mathematical calculation for this is shown with the formula:

D = s / f

D = wavelength in meters

S = Speed in meters per second

F = frequency in cycles per second, also called Hertz (Hz)

(figure available in print form)

Sounds are heard by the ear as either being loud or soft. The loudness of a sound in measured in decibels. Decibels refer to the energy produced by that sound. A human can hear sounds ranging from 0.1 decibels, which is very soft, to sound which measure 120 decibels. Younger people can often hear lower volumes better than older people. (School for Champions/Science/Sound, 6/20/03)

Speed of Sound and Distance

The speed of sound is often confused with the frequency of a sound. It is helpful to remember that the frequency refers to how often while the speed refers to how fast. When discussing the speed of sound it is important to understand that the speed of a sound wave refers to the distance that a point on a wave travels per unit of time. The speed of sound is often stated in units of meters/second. A mathematical equation for this is:

Speed = distance/time

The faster a sound wave travels, the more distance it will cover in the same period of time. The speed of sound depends on the type of properties the wave is traveling through. Two main properties contribute to the speed of a sound wave. Inertial properties refer to the density of the medium that the sound wave is passing through. The greater the inertial properties or the heavier the medium, the slower the wave will pass through. A sound wave will pass quicker through a less dense medium. For example, sound travels quicker through helium then through air, since helium is less dense then air. Elastic properties also affect the speed of sound. These properties refer to how materials maintain their shape under force. Air pressure is an elastic property that affects the speed of sound. The pressure of air will affect the density of the medium, while the temperature of the air affects the strength of the particles passing through the medium. Basically, the speed of sound depends on what the sound wave is passing through. Sound travels faster through solids than liquids and faster through liquids than gases. Sound cannot travel where there is no air, which is why in space it is silent. The speed of sound is about a million times slower than the speed of light. Light travels through air at approximately 300,000,000 meters per second. (Glenbrook/Physics Classroom, 6/10/03)

Conclusion

Sound is one of our five senses that we often take for granted. Although the way we hear sound is often overlooked in our everyday lives it is certainly a fascinating concept to learn about. Throughout this unit I give students the opportunity to explore different mechanisms that help us to hear as well as give them the opportunity to explore different sounds around them. Students gain knowledge about how and why we hear different sounds and also the basics of why we hear sounds differently.

Activity 1: Introduction to Sound

This activity will introduce the students to the concept of sound and hearing. To begin students will be given a paper and a pencil. Students will be given five minutes to write down all the different sounds they hear. For example a lawn mower outside, birds chirping, coughing, etc. After five minutes I will ask students to share the different sounds they have heard.

Next, students will listen to the story *A Listening Walk* by Paul Showers. This book is about a child that takes a walk with her father and hears many different sounds. While listening to the story students will be asked to think of questions or comments they have about sound.

After hearing the story students will be asked to respond in their response journals to the following question. If I went on a Listening Walk, what would help me hear all the different sounds, and why do I hear different types of sound? This question will lead students into the next portion of the lesson, which is the K.W.L chart. This will also get students thinking about how they hear sounds and why some sounds are heard differently.

When students have responded in their journal, they will be given the opportunity to share their responses, which will formulate the K (what we know), and W (what we want to know) portion of our chart.

Activity 2: How our Ears Hear

Throughout the remaining activities students will gather information for our L (what we learned) portion of our chart. I will again begin this lesson with a story about hearing called *Hearing (The Library of the Five Senses and the Sixth Sense)* by Sue Hurwitz. Through hearing this book students will get a basic understanding of how our ear works and how we hear sounds. While reading the book I will ask students to help me label a teacher drawn replica of the ear. In addition to labeling the diagram students will be able to define what each part of the ear does through an inquiry group approach. In this approach the teacher and student work together to acquire answers to a question, rather than the teacher simply spitting out information.

After students have identified the different parts of the ear they will be placed in cooperative learning groups to produce their own diagram of the ear. Students will be given different materials, such as toilet paper tube, string, pipe cleaners, etc., to be used to replicate the ear. This challenging activity will allow students to be creative, at the same time using what they have learned. For example, the cochlea of the ear is spiral, so students will need to use something that will show its shape. This is also a good way to assess students understanding of how the ear works. Students will be able the diagram we have labeled as a guide. Students will also be responsible for their response journals for the following question. What would happen if a part of your ear did not work correctly? The responses will be a great lead in to the next lesson about hearing impairments and the Life of Hellen Keller.

An extension or center activity to this lesson is to have students create flipbooks diagramming and defining the different parts of the ear.

There are two great demonstrations to show how your ears work.

The first is to make an Ear Trumpet.

1. Take a piece of paper and roll it into a cone, with the small end a half- inch opening or larger.
2. Place the cone up to your ear. Be careful not to poke your ear.
3. Listen to a distant sound in a quiet room.

The ear trumpet gathers up sound waves and funnels them into your ear. Because the funnel is bigger than your ear, it gathers more waves. A good response question would be: Why do you think you hear better with the ear funnel?

The second demonstration is to make an ear drum.

1. Stretch a piece of plastic wrap tightly over a cake pan. Hold it in place with a rubber band.
2. Place a small amount of rice on the plastic wrap.
3. Hold a saucepan near and hit it with a spoon.

When you bang on the pan, the sound wave hits the drum and makes it vibrate, just like your eardrum.
(York, 4-5)

Activity 3: Hearing Impairments and the Life of Hellen Keller

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To begin this lesson students will be able to share their responses from the previous lesson. I will then introduce the book *Helen Keller Courage in the Dark* by Johanna Hurwitz. I will explain to the students that as a part of our science unit we will be studying the life of Helen Keller, because she was a person who lived life without the ability to hear sound. Throughout each chapter of the book students will be able to respond to the following journal questions.

1. How would your life be different if you could not hear sound?

2. Do you think Helen Keller would be able to come to Bishop Woods School? Why or Why not?

3. How would Helen's life be different if she were alive today?

4. What would you have done if you were Helen Keller?

Students will also be given the opportunity to learn the Braille alphabet. Students will use the Braille alphabet to write messages to their friends.

A great demonstration to help students identify with how life must have been for Helen, would be to blind fold and ear plug a student and ask them to perform a simple task such as eating a cookie or tying their shoes.

Activity 4: Mechanics of Sound

There are several different activities to demonstrate the mechanics of sound. To begin students need to understand that there are several different aspects of a sound and that vibrations create all sounds.

To demonstrate this, a good activity would be to make a singing string.

1. Loop two feet of thread through two holes of a large button.
2. Tie the ends together with a knot, one on each side of the button.
3. Pull the threads so that you have 6 inches of string on each side of the button.
4. Put your fingers through the loop, and twirl the button around to twist the string.
5. Pull the string in and out. The button will twirl, and you'll hear a humming sound as the string vibrates. (Barron's pg. 67)

Another demonstration to show vibrations is to put a candle out with sound waves.

1. In the middle of an oatmeal box lid, cut a hole the size of a penny.
2. Set the box on its side with the lit candle 4 inches in front of the hole.
3. Lightly tap the other end of the box. The sound is like a drum.
4. Be sure to use safety precautions when conducting this experiment.

The candle will flicker and may even go out. The vibrations will be seen through the flame of the candle. (Barron's pg. 66)

To demonstrate the pitch of a sound wave two simple demonstrations can be used. Play a straw or play on crystal glasses. To play a straw:

1. Fill a bottle of water at different levels.

2. Place a straw in the water, and blow into the other end of the straw.

3. Another variation to this experiment is to simply blow across the top of a soda bottle.

Different pitches will be heard by moving the straw or by adjusting the level of the water. Playing with different crystal glasses will also demonstrate pitch, by running a wet finger around the rim. Again different pitches will be achieved with different levels of water in each crystal glass. (Barron's pg. 68)

Another fun demonstration to show the mechanics of sound would be to use sound tubes. Sound tubes are spun in a circle and produce different tones. The faster you spin the tubes the higher the frequency of the sound. Students will enjoy exploring with boom whackers. Boom whackers are different length tubes that when hit produce different tones. (Teacher Source, 7/30/03)

Some response questions to follow each activity would be:

1. Do you think the sounds would change if milk or soda were added to the crystal glasses?
2. Do you think the string would sing if the button was not round?
3. What other experiments can you think of to demonstrate the different parts of a sound wave?

Activity 5: Speed of Sound:

Students are so fascinated to discover how quickly sound travels. Students will gain understanding of the basic concept of how sound travels through this demonstration.

Singing Spoons:

1. Loop and tie the middle of the string around a spoon handle, then attach the spoon to the string with a piece of tape.
2. Hold the string ends and tap the spoon against a table.
3. Next hold the ends of the string in each ear and repeat step 2.

When you first hit the spoon against the table the sound wave has to travel through air to reach your ear and the sound is weakened. By placing the string in your ear, the sound wave has a direct path to your ear, allowing you to hear the sound more clearly.

An extension to this activity would be to attach more spoons to the end of the string and test the sounds. (York, card number 8)

Some response questions for this demonstration would be:

1. Do you think a fork or knife would work the same?
2. What do you think would happen if the fork was plastic?
3. What if you did not have any string, what else could you use to conduct this experiment?

Activity 6: Culminating Activity

As a culminating activity to this unit students will be placed in cooperative learning groups. Each group will be given guidelines to follow, the outcome will be a board game based on one of the following topics.

1. Your Ear
2. Helen Keller
3. Sound Waves
4. Speed of Sound

Students will be responsible for creating the board, rules and directions for their games. The questions to be answered in each game will come from information students have learned throughout the unit.

Student Reading List

Baker, Wendy. *Sound: The Hands on Approach to Science.* Creative Publishing. 2002. Great book for experiments and activities that explore sound. Teaches students scientific method.

Chapman, Jane. *Very Noisy Night.* Penguin Putnam Books. 1999. Little mouse can't sleep because of all the noises in the night. Gets students to notice all the different sounds around them everyday.

Cole, Joanna. *The Magic School Bus Explores the Senses.* Scholastic Publishing Company.2001. Ms. Frizzle explores all five senses, including sound and hearing

Collins, Beverly. *You Can't Smell a Flower with your Ear.* Putnam Publishing Company. 1994. This book explores many fascinating questions about sound and how we hear. This book will get students thinking.

Hewitt, Sally. *Hearing Sound* Scholastic Library Publishing. 1998 Another book, which explores how we hear. Also explores creating different sounds.

Johnstone, Leslie. *Science Experiments with Sound and Music.* Sterling Publishing. 2002. Great hands on approach experiments. Some experiments explore different types of musical instruments.

Pfeffer, Wendy. *Sounds All Around.* Econo-Clad Books. 1999 Demonstrates that sound is all around us. Great eye opener for students.

Rogers, Kristeen. *Light, Sound and Electricity.* Usborne Publishing. 2002 Another activity book for students, which also includes experiments for light production.

Showers, Paul. *The Listening Walk.* (Let's Read and Find Out Science Book). Harper Collins Children's Book. A little girl and her father go for a walk and observe different sounds. Another great book to get students to observe sounds around them.

Vancleave, Janice. *Physics for Every Kid: 101 Easy Experiments in Motion, Heat, Light, Machines, and Sound.* Wiley, John and Sons Inc. 1991 Another experiment book for hands on activities using household materials.

Teacher Resources

Barron's, *Science Wizardry for Kids.* Barron's Educational Series. 1992. Great hands on experiments with simple materials. Explores different scientific areas.

Cassidy, John. *Explorabook: A Kids' Science Museum in a Book.* Klutz Press.1991

More experiments that deal with sound, magnets, homemade science and optical illusions. Some materials are included in the book.

Hann, Judith. *How Science Works.* Readers Digest Adult. Many answers to your questions can be found in this book. This book gives explanations about how different things work.

Paulu, Nancy. *Helping Your Child Learn Science* . U.S. Department of Education. 1991. More hands on experiments with household materials.

Potter, Jean. *Science in Seconds for Kids.* John Wiley 7 sons, Inc. 1995. Quick and easy science experiments kids can do alone.

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Hurwitz, Johanna. *Helen Keller Courage in the Dark.* Random House. 1997. Chapter book which explores the life of Hellen Keller. This is an easy reader book.

York, Penny. *Experiment Cards (Sound)* Dorling Kindersley. Step by step directions for many sound experiments.

http://www.scholastic.com/magicschoolbus/games/teacher/sound/print.htm

http://www.ptc.dcs.edu/hasp/Sound

http://www.glenbrook.k12.il.us/gbssci/phys/Class/Sound/u1112a.html

http://www.umanitoba.ca/faculties/arts/linguistics/russell/138/sec4/acoust1.htm

http://www.rnib.org.uk/wesupply/fctsheet/keller.htm

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http://www.state.ct:us/sde/dtl

http://faculty.washington.edu/chudler/bigear.html

http://school-for-champions.com/senses/hearing.htm

www.nichcy.org/pubs/factsheet/htm

www.teachersource.com