Chapter 25

THE NEIGHBORHOOD TELEPHONE SYSTEM

Laurie lived next door to Maria. They were best friends and had been since kindergarten. Now, in the fourth grade, they seemed to spend more time together than ever. Every evening after supper they would be on the phone, yakking away about all sorts of things.

"Hey, you have been on the phone for an hour!" said Maria's dad. "I'd like to use the phone too."

"Right!" said her mom. "I'm expecting a call from Auntie Felicia tonight."

"But I'm taking to Laurie," begged Maria. Suddenly Maria had an idea. "Hey, why don't you and Laurie's parents get us our own phones; cell phones might be really nice? Then we wouldn't be on your phone all the time."

"Do you have any idea how much the monthly bills are?" said her dad. "For Pete's sake, you live right next door. You can practically talk to each other from your bedroom windows…." Suddenly he stopped. "That's it!" he cried. "You can talk to each other from your bedroom windows."

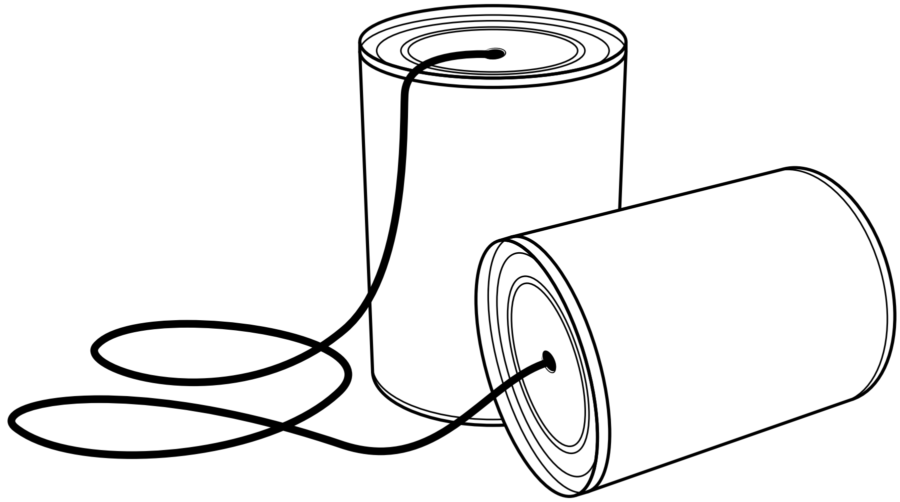
"Daaaad," Maria laughed, "everybody in the neighborhood would hear us shouting at each other from our windows!"

"No, no, no!" exclaimed Maria's dad. "You can use TCTS. Completely private and really, really, cool. And the price is perfect!"

"Okay, I give up, what is TCTS?" asked Maria.

"No mystery. It's a simple device, two tin cans connected by a string. Now can you guess what TCTS stands for?" asked her dad.

This all sounded interesting so Maria talked to Laurie the next day and they decided to give this idea a try. With a little help from Maria's mom and dad, they used two empty tomato cans connected by a long string knotted on the inside of the cans, so that it would not come out of the hole punched in the can. It looked like this.



In no time at all they had the telephone system set up between the windows of their rooms and were ready to try it out. Laurie held her can up to her ear and Marie talked softly into the can on her side, hoping that her voice would travel along the string to Laurie. Nothing! Their mothers were waiting below and shouted up, "you have to have the string between the cans pulled tightly."

The girls pulled the string tight and soon they were talking to each other across the distance although the words were not always clear.

"Why does the string have to be tight?" shouted Laurie.

"Good question. Think about it a while and we'll talk," said Laurie's mom.

"What's so magic about the string?" asked Maria.

"Another good question!" said Maria's mom. "Another question to think about."

"How can we make it clearer? Sometimes I can barely make out your words," asked Laurie.

"How about using bigger cans?" asked Maria. "Or maybe a plastic or paper cup instead?"

"Or, using bigger string, maybe?" replied Laurie.

"Or use something other than a string. Maybe a wire?" added Maria's mom. "Maybe the sound will travel better through a wire."

"Looks like we have some experimenting to do," said the Maria.

Purpose

This story has a two-pronged purpose. One has to do with learning something about sound (science) and the other has to do with learning about using science to modify the things in the world to solve human problems (technology).

Few adults have not had the opportunity to use a "tin can" telephone (TCT) during his or her childhood. The goal of transmitting sound across a distance has been around for a long time. It is even rumored that Alexander Graham Bell, the inventor of the telephone, played and experimented with one as he was closing in on his invention that would change the world. Obviously Bell was trying to eliminate the string but the principles of vibration and transmission of sound waves were still the guiding principles. Bell found a way to transmit the vibrations electrically, eliminating the need for direct contact between the speakers. This story uses the TCT as a focus for inquiry into the transmission of sound waves along a medium and also provides an opportunity for kids to try their hand at improving a simple device so that it works better. Students will experiment with various parts of the TCT changing variables and trying to find the best combination for optimum transmission of their voices.

In this electronic age, it is probably difficult for children to imagine a time before cell phones, television, blackberries, palm pilots, and portable media systems. Yet, it is often exciting for children to backtrack and experience the earlier days before modern communication and information technology became a way of life. School curricula are full of demonstrations of sound transmission through solid and liquid media but here in the TCT story is an opportunity to investigate an old toy and find out what makes it tick. There is plenty of room for the science and technology aspects of the standards to be applied. Building a better mousetrap is usually exciting for students and here is one that gives instant feedback, and makes changing variables easy and fun. If you play with one before you take the idea to your students you will find that several variables make a difference in sound transmission. It will also help you to be prepared with different materials for students to use in their experimentation. You will also notice the inclusion of the technology standards in this background material so that you can see what types of technology standards as well as science standards can be met.

Related Concepts

- Waves
- Sound transmission
- Energy
- Technological design
- Sound
- Vibration
- Energy transmission

Don't Be Surprised

Children may reject the use of nonmetallic objects to design the telephone since they usually think of sound coming from vibrating metals such as cymbals or strings. Children also think of sound as a substance that moves from the sender to the receiver. On the other hand, those who believe in sound emanating from vibrating objects may immediately connect the string or wire connecting the "cans" as picking up vibrations and transmitting sound.

Content Background

Sound waves, like all waves, are energy waves. All waves transmit energy. Sound waves emanate from vibrating objects. They travel through air or any other medium but can be distorted by other sounds or anything that can disrupt the medium through which the waves travel. Vibrations in the originator of the sound such as vocal cords, drum skins, objects falling on pavement, clapping hands, or a multitude of banging or clanging can generate sound waves, which then travel through gas, liquid, or solid but not through a vacuum. This is because they need to excite molecules in the medium so that they transfer the energy of the original sound to nearby molecules, which then transfer them on to others in the form of a sound wave. These waves are compression waves and might be visualized as lines on a bar code, pushing against each other in a uniform pattern so that the sound travels from one end to the other. You may remember a science teacher from your past placing an alarm clock in a vacuum jar, and removing the air from within it. If the clock was ringing, the sound stopped when the air was removed. There were no molecules of any sort to be excited by the energy generated by the alarm. This of course brings up the old philosophical quandary, "If a tree falls in a forest where no one is present, does it still make a sound?" Sound needs no ear to hear it. It occurs whether one hears it or not.

Sound waves can bounce off objects and appear to come from different directions. If you have been in a noisy public place, surrounded by hard, bare surfaces, you may remember how difficult it is to converse with people near you. Sounds from other conversations and other noise bounce off these surfaces and literally fill the room with their presence. If you have experienced an echo, the same principle applies except that the bouncing sound wave is more focused and not mixed with other sounds.

Sound waves can be amplified by electronic means or by acoustic devices such as megaphones. Guitars, violins, and other stringed instruments make use of an acoustic amplifier by designing a way for the vibrating string to set up vibrations in an attached or surrounding structure. This changes the volume of the sound you hear. In the TCT, the can or cup into which the child speaks vibrates according to the sound waves made by the speaker. These sound waves are transferred to the string or wire and transmitted through the medium to the other cup, which in turn vibrates in the same way and also amplifies the sound transmitted down the string to the listener. It may be an important clue for you to know that amplifiers usually have cones made of paper in them.

Different materials vibrate according to their structure. You will find that metal cans are not the best amplifiers since the construction of the can will cause different frequencies to travel at different speeds in the metal and produce garbled sounds. Plastic cups may be used to see how they act as amplifiers.

An object can produce sounds of varying pitches, giving a higher or lower sound. This usually is accomplished by changing the speed of the vibrating object. If you are plucking a rubber band or a guitar string, you may make the pitch higher or lower by either stretching (higher) the vibrating strand or relaxing it (lowering). You may also use a thinner string (higher) or a thicker string (lower), which, respectively, makes the plucked string vibrate faster or slower.

There are other things that vibrate, which are not so easy to see. Let's say someone drops keys on a tabletop. You hear the sound and from experience recognize the sound as keys hitting a tabletop. This is a combination of your brain's memory of past experiences and your ear's ability to capture the resulting sound wave and send the vibration to the brain through the auditory nerve. But I just said that all sound was caused by vibrations so what caused the sound wave and vibration? I didn't mention any strings or drum skins, just keys and a table. Here is the problem that escapes most adults and children. Both the table and the keys vibrate as the keys hit the table and set the sound wave energy in motion and straight to our ears and ultimately our brains. We live in a world of sound and most of us hearing folks have learned to identify the sound vibrations that enter our ears. It is a good thing too, since screeching tires, auto horns, and other alarms help us to avoid nasty confrontations with moving objects larger than we are.

Technology is an important aspect of science and technology education. In this story, there is an opportunity for children to see the aspects of problem solving and its relationship to design. The use of the term *technology* in the Standards is often confused with "instructional technology," which includes computers, digital microscopes, and other devices that help science teachers conduct their lessons. The difference is in goals. In the Standards, technology aims at giving children the opportunity to modify the environment to meet human needs. There are a series of five stages, which provide a framework for teachers to use in planning and assessing outcomes in technology. These five stages are:

- Stating the problem
- Designing an approach
- Implementing a solution
- Evaluating the solution
- Communicating the problem, design, and solution (NRC 1996, p. 137)

These stages are not to be construed as steps but as guidelines. Sometimes the objective will be to evaluate, for example, the relative properties of paper towels or shampoos. Other times they are guidelines to improving the mousetrap or in this case, the TCT. And at other times, the development of a specific invention or a device needed to solve a problem or challenge will be necessary.

Related Ideas From the National Science Education Standards (NRC 1996)

K–4: Position and Motion of Objects

- Sound is produced by vibrating objects. Changing the rate of vibration can vary the pitch of the sound.

5–8: Transfer of Energy

- Energy is a property of many substances and is associated with heat, light, electricity, mechanical motion, sound, nuclei, and the nature of a chemical. Energy is transferred in many ways.

K–4: Abilities of Technological Design

- Identify a simple problem.
- In problem identification, children should develop the ability to explain a problem in their own words and identify a specific task and solution related to the problem.
- Propose a solution.
- Students should make proposals to build something or get something to work better; they should be able to describe and communicate their ideas. Students should recognize that designing a solution might have constraints, such as cost, materials, time, space, or safety.

5–8: Abilities of Technological Design

- Design a solution or product.
- Students should make and compare different proposals in the light of the criteria they have selected. They must consider constraints—such as time, trade-offs, and materials needed—and communicate ideas with drawings and simple models.
- Implement a proposed design.
- Students should organize materials and other resources, plan their work, make good use of group collaboration where appropriate, choose suitable tools and techniques, and work with appropriate measurement methods to ensure adequate accuracy.
- Evaluate completed technological designs or products.
- Students should use criteria relevant to the original purpose or need, consider a variety of factors that might affect acceptability and suitability for intended users and beneficiaries and develop measures of quality with respect to such criteria and factors; they should also suggest improvement and, for their own products, try proposal modification.

Related Ideas From Benchmarks for Science Literacy (AAAS 1993)

K–2: Motion

- Things that make sound vibrate.

6–8: Motion

- Something can be "seen" when light waves emitted or reflected by it enter the eye—just as something can be "heard" when waves from it enter the ear.
- Vibrations in materials set up wavelike disturbances that spread away from the source. Sound and earthquake waves are examples. These and other waves move at different speeds in different materials.

K–2: The Nature of Technology

- Tools are used to do things better or more easily and to do some things that could not otherwise be done at all. In technology, tools are used to observe, measure, and make things.
- When trying to build something or to get something to work better, it usually helps to follow directions if there are any or to ask someone who has done it before for suggestions.
- People alone or in groups are always inventing new ways to solve problems and get work done. The tools and ways of doing things that people have invented affect all aspects of life.

K–2: Design and Systems

- People can use objects and ways of doing things to solve problems.

3-5 Design and Systems

- Even a good design may fail. Sometimes steps can be taken ahead of time to reduce the likelihood of failure, but it cannot be entirely eliminated.

6–8: Design and Systems

- Design usually requires taking constraints into account. Some constraints, such as gravity or the properties of the materials to be used, are unavoidable.
- Technology cannot always provide successful solutions for problems or fulfill every human need.

3–5: The Nature of Technology

- Throughout all of history, people everywhere have invented and used tools. Most tools of today are different from those of the past but many are modifications of very ancient tools.
- Any invention is likely to lead to other inventions. Once an invention exists, people are likely to think up ways of using it that were never imagined at first.

Using the Story With Grades K–4

After reading the story, students should be asked to list their statements explaining why the TCT works. You will get a great many ideas of how sound gets from one person to another. It is really necessary that children have an idea of how sound travels from the vibrations set up in the cup, through the line, and is amplified in the receiving cup. List these on a "Best Thinking" chart for future referral. Next, try to elicit from the children their ideas about what kinds of things can be changed in the TCT in order to test what changes might get it to work better. You may also help them to realize that they need to decide what "better" means. Does louder make it better? Does hearing words more clearly make it better? Since the purpose in the story was to allow the girls to talk to each other, perhaps the latter is more important but the former can be a responding variable too, if the children so desire. They must be clear on what they are measuring and should keep notes and drawings in their science notebooks. Obviously, the activity will require working in pairs at a minimum since the TCTs must be far enough apart to test their efficiency.

Making the phones is a simple process but may need the help of an adult for safety's sake. First, make sure that the cans are the same size, are open on one end, and that any jagged edges are either eliminated or covered over with heavy tape. A small hole should be made in the center of the intact end so that a string, wire, thread, or other medium can be pushed through the hole, knotted on the inside (so that it will not slip back out) and tested by pulling. Now that the cans are ready, the children can test them and see if they are able to understand each other. They will certainly hear some sounds although the exact words may not be clear. Thus comes the need to try different materials to see if the system can be improved. You are now into the technology standards as well as the science standards.

You may want to have on hand, larger cans, paper cups of varying sizes, plastic cups of varying sizes, wire, cotton twine, plastic cord, and so on. The cord's length may also be a variable the children want to test, but for starters you may want to suggest that four to five meters be standard for all trials. If the children forget to keep the strings taut, reread the part of the story that makes this point. With younger children it will probably be necessary to allow them to experiment with vibrating objects and make sounds so that they can see that the string must be free to vibrate. If they use rubber bands, help them to see that the bands must be tight in order to produce a sound. If they stretch balloons over cans like a drum skin, they can also see the amplification caused by the sound box. Many of the tried-and-true sound activities will be more meaningful once they are attached to the story. Finally the children will probably come to the conclusion that the larger paper cups and cotton twine will work the best but their results may vary. The most important thing is that they have a better understanding of how sound travels through various media and will have experienced the technology techniques involved in improving a device.

Using the Story With Grades 5–8

Once again I recommend that you read the suggestions given for grades K–4 before moving on to this section. Many of your students will own cell phones and will already have caused a problem in your classroom. They may have difficulty in understanding the relevance for improving this "low tech" toy. It helps to turn this story into a technology-oriented task by asking them to become a toy company R & D (Research and Development) department given the task by the president or CEO of the company to produce the best product for sale to the public. In this case, you may want to develop with the help of the class a rubric with minimum standards set up that must be met. In other words, each group of students must develop a telephone that performs to standards set up by the entire class. Meeting these standards becomes the goal for those wishing to receive the highest grade and since they have been involved in setting the standards, they are involved in the evaluation of their product and their group's effort.

I have used a letter "written" by the company president giving the R & D group the challenge for producing a good toy. The letter should state that including the principles of how the toy works is important because written material describing these principles will be distributed along with the toy. They might also consider cost and suggest a price with a profit margin if you would like to integrate your math, science, and technology. You may want to use this material as an additional embedded assessment tool. Another way of testing their understanding and ability to explain the principles involved is to invite a class of younger students to your class so that your students can help them go through the process of developing the best toy. Regardless, I think your students will end with a better understanding of the transmission of sound energy as well as a more realistic view of the technology of improving a product.

Related Books and NSTA Journal Articles

Brown, R., and K. Boehringer. 2007. Breaking the sound barrier. *Science Scope* 30 (5): 35–39.

Cottam, M. 2006. Waves on the fly. *Science Scope* 29 (5): 22–25.

Farenga, S., and J. Ness. 2002. Sound science of the symphony: Sound intensity. *Science Scope* 25 (5): 50–53.

Palmer, D. H. 2003. Modeling the transmission of sound. *Science Scope* 26 (7): 32.

Tolman, M., and G. Hardy. 2001. Sound fun with noisy cups. *Science and Children* 38 (7): 6.

Wise, K., and M. Haake. 2007. Coffee can speakers: Amazing energy transference. *Science and Children* 44 (7): 36–40.

References

American Association for the Advancement of Science (AAAS). 1993. *Benchmarks for science literacy*. New York: Oxford University Press.

National Research Council (NRC). 1996. *National science education standards.* Washington, DC: National Academies Press.