How can I design a cellular phone that is safer to use?

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Institute: University of Michigan

Country: USA

Subject: Science in context in society - Design-based science

Grade level: 10-12 graders

Curriculum content: EM Radiation

Kind of activity: Critical reading and group activity

Anticipated time: 4-5 lessons of 45 minutes each

Objectives/Competences: Group activity and critical reading of an article

Rationale

The curriculum, *"How Do I Design a Cellular Phone that is Safer to Use?*" was developed in the Center for Highly Interactive Computing in Education (Hi-ce) at the University of Michigan by one Israeli and two US science educators. Hi-ce has a history of involvement in science education reform in both urban and suburban settings. Over the course of the 1999-2000 school year, Hi-ce developed reform-focused science curricula. The development of the science curricula was only one component in a larger project called the Primary Sources Network (PSN), a federally funded Technology Innovation Challenge Grant. The PSN project strives to create both science and social studies curricula that meet several goals, one of which is to create a framework for understanding how primary sources can be used to support learning in high-school classrooms and to adapt, design, and develop learning technologies to support the use of primary sources. The new curricula involve topics that are of popular interest to most students. Students learn through the use of computers and learn standards-based science content while studying and designing artifacts.

Goal:

The goal of this learning set is to:

- Introduce students to the project's goals and objectives
- Provide an overview of the design process for the students
- Introduce the students to the concept of a target market
- Have the students produce their first concept drawing

Lessons Overview:

Class 1

1. Assign students to new teams
2. Project goals and objectives
3. ABC News video & reading
4. Defining design slide show
5. Initial concept sketch

Task description

In this activity students are introduced to the design project and they are provided with an overview of some of the activities they will be participating in. This lesson introduces the context of their design project and it provides the motivation to hook them into being interested in the project. Students watch an ABC news video on cell phone safety and they participate in an activity that has them evaluating the facts and opinions found in the video. The teacher gives an overview of the design process and the students participate in an activity that introduces them to the concept of a target market. Students end this lesson by creating their first concept sketch of their ideas and getting feedback in a pin up.

Background: How do telephones work?

Every telephone has four basic functional parts: a microphone, a speaker, a transmission unit and a dialing unit.

The Microphone

The microphone's operation is based on a physical principal called magnetic induction (these are excellent computer simulations of the operation of a microphone).
The coil is attached (glued) to the center of the diaphragm, which is not much more than a thin tightly stretched piece of paper.
When one speaks, he creates sound waves, which are areas of high and low pressure. These waves advance and strike the membrane. When an area of high pressure reaches the membrane, it forces it inwards. When an area of low pressure reaches the membrane, it pulls it outward. So the inward and outward motion of the diaphragm is a result of pressure differences in the sound wave. We say that the diaphragm's motion resembles the change of pressure in the second wave, or is analogous to it.
When the diaphragm moves, it moves the coil with it, since it is glued to it. When a coil moves in a magnetic field, an electric voltage is introduced between its ends – this is the physical principal of magnetic induction. Since there is a magnet situated inside the coil, the coil senses a magnetic field, and therefore when it moves with the diaphragm, an electric voltage is created between its ends. This is analogous to the sound waves which caused the voltage to be created.

The speaker

The speaker is very similar to the microphone, except its operation is exactly the opposite. When an external electric voltage is applied to the ends of a coil while the coil is in a magnetic field, a force is generated on the coil. This force causes the coil to move back and forth, depending on the direction of the force, which in turn depends on the behavior of the voltage which is applied to the coil's ends.
When the coil moves back and forth, the diaphragm moves along with it, since they are glued together. When the diaphragm moves back and forth, it pushes and pulls the air situated next to it, creating areas of high and low pressure, that can then propagate outdoors, creating a sound wave, which we can hear.

The operation of the microphone and the speaker

The operation of the microphone and the speaker is almost identical in all types of phones. The transmission unit, however, can differ greatly between different types of phones, especially between conventional phones and cellular phones.

The job of the transmission unit is to take the voltage created by the microphone of one phone and transmit it to the speaker of another phone, where it will cause sound waves to be generated at a speaker. The sound waves which created an electric voltage at one phone, are reproduced at another phone, causing the listener at the second phone to hear what the person at the first phone spoke.

In a conventional phone, the voltage created by the microphone is amplified (made bigger and stronger) and then sent down a telephone wire to another phone. In a cellular phone, the voltage created by the microphone is digitized (translated into a code called the **digital code**). This encoded voltage is then translated into an electromagnetic (EM) wave with a microwave wavelength. This EM wave is then transmitted by the antenna in all directions. The antenna of another cellular phone can receive this EM waves, and translate it back in an electric voltage which can then be used to drive the speaker.

Both systems (conventional + cellular phones) suffer from the same problems: the signal created by the transmitting phone (electric voltage in a conventional phone, and EM wave in a cellular phone), is too weak to reach the receiving phone, wherever it may be. This problem is solved with conventional phones by having amplification stations located along the line connecting the two phones; Whenever the transmitted signal becomes too weak, it is boosted and resent on its way.

With cellular phones, the solution is more creative. The country is divided into cells, so that there is a small overlap between adjoining cells. In this way, no matter where you are located, you are always situated inside at least one cell. A central cellular antenna is located at the center of each cell. The job of this antenna is to receive all the messages broadcasted by all the cellular phones situated in its cell, and to send to all the cellular phones in its cell. In this manner, a cellular phone needn't transmit an EM wave strong enough to go half the way around the globe – it just needs to be strong enough to reach the central antenna of the cell, where the phone is now located. Once the central antenna has received a message from a cellular phone under its jurisdiction, it transmits this message to the central antenna in charge of the cell where the receiving phone is located. The transmission between the two central antennas is done with standard telephone lines or by satellite.

The dialing unit

The dialing unit is the same on all types of modern phones. It is a 3x4 matrix. Each column and each row have a certain frequency (tone) assigned to them. Each time you press a button, the dialer produces two tones, one for the column of the botton you pressed, and one for the row. So, if you press 7 keys, the phone generates 7 pairs of tones. These tones are transmitted much like the signal you generate when spreading is transmitted. The signal reaches an exchange where the 7 pairs of tones are received and translated both into 7 numbers. The exchange has a computerized "phone-book", so it knows by the 7 numbers it received for the call is meant. It then sends a "wave-by" signal to the call recipient that causes the phone to ring.

Electromagnetic Radiation

Purpose:

- Relate to the driving question
- Study different science concepts and issues
- Learning through active problem solving
- Learn science in a design frame work
- Learn science with a historical approach

Overview

This chapter deals with different kinds of EM and the possible hazards associated with it. The EM topic serves as a framework to the particle theory and the modern model of the atom.

Science understanding for the teacher

In a cellular phone, the voltage created by the microphone is digitized (translated into a code called the **digital code**). This encoded voltage is then translated into an electromagnetic (EM) wave with a microwave wavelength. This EM wave is then transmitted by the antenna in all directions. The antenna of another cellular phone can receive this EM waves, and translate it back in an electric voltage which can then be used to drive the speaker.

What are electromagnetic waves?

An electromagnetic wave (EM) is partly electric and partly magnetic. The energy transmitted by electromagnetic waves is called **radiation**. EM include: radio waves, microwaves, infrared radiation, visible light, ultraviolet radiation, X rays, and gamma rays. This types of radiation are listed in order of wavelength, from longest to shortest. The range of EM waves, or the EM spectrum, is shown in figure 1. (*Conceptual Physics, p. 408*)

Each type of the electromagnetic radiation has several common properties (ChemCom, p. 276):

- It is a form of energy and has no mass.
- It travels at the speed of light.
- It can travel through a vacuum; unlike sound or ocean waves, its movement does not depend on a medium such as air or water to “carry” it.
- Atoms emit it as they decay, or after they are energized, such as heating the tungsten filament in a light bulb or lightening the fuse that explodes the compounds in fireworks.
- It moves through space as packets (bundles) of energy called **photons**. Each photon has a characteristic frequency, such as the frequencies of radio waves received by radio.
- The energy of photons is related to their frequency – the higher the frequency of electromagnetic radiation, the higher its energy.

Are there health hazards associated with electromagnetic energy?

The interaction of biological material with an EM source depends on the frequency of the source. **The frequency** is the rate at which the electromagnetic field changes direction and is given in Hertz (Hz), where one Hz is one cycle (change in direction) per second, and one megahertz (MHz) is one million cycle per second.

At the extremely high frequencies of X-rays, electromagnetic particles have sufficient energy to break chemical bonds. This is how X-rays damage the genetic material of cells, potentially leading to cancer or birth defects. At lower frequencies, such as radio waves, the energy of particles is much too low to break chemical bonds.

How did the theory of particle structure develop?

The accepted theory on the structure of matter is the theory of particle structure. The hypothesis that matter is composed of small particles is an ancient one that originated with the Greek philosophers. The second chapter dealt with the work of the alchemists in the framework of Aristotle's theory, but even during Aristotle's time there were those who disagreed with his opinions and the explanations he offered on the structure of matter. His sharpest critics and opponents were the followers of Leucippus and Democritus who claimed that if they were to take matter and continually divide it, they would finally obtain very small particles that could be divided no further - **atoms**.

At the beginning of the 19th century, the English physicist John Dalton wrote: "The final particles of all simple bodies are atoms that cannot be further divided. These atoms are balls and each has a weight that characterizes it and which can be described by a number".

The first sentence is in fact a repetition of the wording of the Greek philosophers. The innovation proposed by Dalton is contained in his second sentence. He was the first to ascribe weight to atoms and he determined that all the atoms of a given element are identical and are different from those of other elements.

Dalton's greatness is also demonstrated by the fact that he proposed a way of concretizing the model that was his brainchild. To assist his students in understanding his ideas, he prepared different sized balls of clay and other materials and used them as atomic models, and he also suggested using written circles to symbolize the atoms.

With the help of his atomic models, Dalton tried to explain the structure of compounds. He claimed that a "particle" of a compound was composed of a constant number of atoms of the elements composing the compound. For example, he described the "particle" of carbon monoxide by combining a carbon atom with an oxygen atom, and carbon dioxide by combining one carbon atom with two oxygen atoms. Some of the theories proposed by Dalton on compounds were incorrect. He thought, for example, that a "particle" of water was composed of one hydrogen atom and one of oxygen and he also thought that gaseous elements like hydrogen, oxygen, nitrogen and so on, contained single atoms.

We know today that various substances are not built of single atoms but of clusters of two or more that are joined. These clusters are called molecules. A hydrogen molecule, for example, is composed of two chemically-linked hydrogen atoms whose formula is H_2. In the oxygen molecule, O_2, there are two linked oxygen atoms. The hydrogen and oxygen molecules are examples of diatomic molecules, or in other words, molecules composed of two atoms.

There are also more complex molecules. In water molecules, for instance, there are two hydrogen atoms and one oxygen atom. Each of the hydrogen atoms is linked to the oxygen atom and thus the formula of the water molecule is H_2O.

Despite the fact that Dalton erred in some of the ideas he proposed, even today we are still helped by models that resemble those he developed because with them, it is convenient to illustrate the structure of elements and of simple or complex compounds.

Why is Dalton's atomic model inadequate?

Although Dalton's atomic-molecular model explained a number of the properties of matter, it proved to be inadequate. As we have mentioned, according to Dalton's model the atom is a rigid ball that cannot be further divided and the atoms of one element are different from those of another. Today, we know of over one hundred different atoms and therefore, according to Dalton's model, we should have assumed that there are over one hundred types of "successive balls", each of which is different from the other. This picture was changed with the discovery of the fact that atoms are built of subatomic particles. Various experiments have indicated the electrical properties of atoms, but a new model that explained these facts was only developed after experiments conducted from 1875 by Crooks and Thomson. Thomson summarized these experiments thus:

"We saw that the corpuscles (negatively charged particles) are always identical, with no relation to the properties of the matter which is their source. This, together with the fact that their mass is very small relative to that of the atom, leads us to assume that they are part of the atom. Or in short, the corpuscles are a vital component of the structure of the atoms of the various matters..."

To explain the fact that the atom is electrically neutral, Thomson assumed that it was a positively charged ball in which were embedded negatively charged particles (electrons), "like currants in a cake".

Thomson knew nothing of the existence of positive particles (protons) in the atom, and in order to explain electrical conductivity all he had to do was assume that in the atom, apart from the negatively charged particles, the electrons, there was also a positive charge.

The latter years of the last century and the first years of the present one saw discoveries that made a great contribution to understanding the structure of matter, and it very quickly became clear that model did not explain facts that were discovered later.

Henry Becquerel was a French scientist who was interested in the study of substances which, after irradiation by the sun, were capable of continuing to emit light. One of the substances he tested was a sample containing the element uranium, put the sample in the sun and later placed it on a photographic plate in order to test the properties of the radiation emitted by the substance.

One day, while these experiments were at their height, the sky clouded over and was unable to continue with his work. He packed up the substance and put it into a dark drawer on top of the covered photographic plate. The bad weather continued but he nevertheless decided to develop the plate and to his great surprise he found a dark stain, despite the fact the plate had been covered in black paper.

Becquerel repeated the experiment numerous times and always found that the uranium sample continued to emit a mysterious radiation that even without previous exposure of the uranium sample to light, continued to be emitted. He called this phenomenon **radioactivity**.

Becquerel's experiments and the phenomenon he had discovered reverberated around the scientific community of the time, and numerous scientists began testing it and searching for additional radioactive materials.

The discovery of radioactivity brought about an even more important breakthrough in the field of the internal structure of the atom. One researcher who made a great contribution to the study of radioactive radiation was the New Zealand physicist, Earnest Rutherford, who conducted experiments whose results were extremely surprising and which repudiated the model proposed by Thomson. Rutherford proposed a new model, **the nuclear atom model**, that would explain the results. According to this model, the main part of the atom's mass is concentrated in an extremely small, positively charged central nucleus, whose diameter is 0.000000000001 cm^2. In the large vacuum around the nucleus, whose diameter is 0.00000001 cm^2, there is a correct number of electrons for balancing the positive charges in the nucleus (the protons). Such a difference in size is difficult for us to absorb, but the following thought might help. Were we able to increase the size of the nucleus to the size of the period at the end of this sentence, it would be the size of a thirty-story tower building.

Rutherford tried to explain the form in which the electrons are arranged around the nucleus with the help of a familiar system - the solar system and the planets that surround it - with the central nucleus of the atom surrounded by electrons revolving around it.

As you learned in the previous chapters, a scientific model must be capable explaining facts known at the time the model is proposed, and also those discovered afterwards, and indeed, the way in which present day scientists described the structure of the atom observes the basis principle proposed by Rutherford; the principle which states that the atom has a extremely small central nucleus surrounded by electrons.

The atom's nucleus*

According to the model presented, the basic principles of which are still accepted today, the protons, which carry the positive charge, are concentrated in the nucleus. In an atom that is neutral from an electrical standpoint, the number of protons is equal to the number of electrons around the nucleus. Apart from the protons in the nucleus, which carry a positive electrical charge, there are also neutrons which are particles that do not carry an electrical charge and the mass of each of them is approximately equal to that of a proton. The properties of an element are determined by the number of protons in their atoms' nucleus. However, in the nuclei of atoms of the same element there is likely to be a different number of neutrons.

In the majority of hydrogen atoms, for example, over 99.9% of them, the atom's nucleus has only one proton. In 0.015% of all the hydrogen atoms, the nucleus also contains, in addition to the proton, one neutron. In **all** the atoms' nuclei of the element uranium there are **92** protons and in the majority of them (99.27%) there are **146** neutrons, but in 0.72% of all the atoms there are **92** protons in the nucleus and only **143** neutrons. The ratio of protons to neutrons in the nucleus is of great importance in determining the atom's degree of stability. Atoms in whose nuclei there is an identical number of protons but a different number of neutrons are called **isotopes**.

Bibliography

- Physical Science, Holt Science & Technology, Holt, Rinehart and Winston, 2001, pp. 268-297
- www.primarysources.org/
- "Energy and the Human Being" by R. Ben-Zvi. The Science Teaching Department, Weizmann Institute of Science, Rehovot, Israel

A Bibliography's rules must be used (American Psychological Association).

Teacher notes

Planning Calendar

Learning Set 1 Can I become sick by using a cell phone? ***Session 1*** Radiation health hazards	Day 1 ***- Determining the Driving Question*** - Guided reading of the article "Wireless Worries?" by Brian Ross (ABCNEWS 20/20) - Structured reading sheet on health questions and possible design solution - Class discussion

Additional suggestions:

Students' activities

- A breakdown of a conventional phone + a cellular phone.
- A breakdown of a speaker.

- A breakdown of a microphone.
- Computer simulation of magnetic force + magnetic induction.
- Explanation of sound waves + computer demo of voice general waves.
- Why does high-pressure push and low-pressure pull?
- Simulation of a human ear with the eardrum.
- Define of frequency.
- Apply sine waves (signal generator, or sound-blaster) to microphone and measure output voltage frequency.
- Apply different sine waves (signal generator, or sound-blaster) to speaker.
- Amplify sine waves – hear the difference, see the difference with a voltmeter.
- Measure voltage decay over distance with high – independence wires of different length.
- Amplify signal weakened because of decay back to its original strength.
- General explanation of EM waves and the different wavelengths characteristics.
- Demonstrate that you can "see" IR.
- Demonstrate the r Law.
- Show project IRIDIUM for geostationary communication sattelites.

Listen to phone tones.

Reference for further information: "*Telephone*", *Microsoft Encada 98 Encyclopedia. 1993-1997 Microsoft Corporation.*