Teleportation and Time Travel: Science or Fiction?

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There once was a lady named Bright,
Who traveled much faster than light.
She departed one day, in a relative way,
And returned on the previous night.
-Unknown

INTRODUCTION

Teaching my enrichment classes I have found that students are fascinated by the idea of time travel. They want to know if it will ever become possible to visit people and places of the past or future. They are equally intrigued by the idea of teleportation—disappearing from one place and reappearing somewhere else, thousands of miles away.

My unit addresses the concepts of teleportation and time travel as depicted in popular movies and television series e.g. *Back to the Future* and the *Star Trek* series. It attempts to explain the ideas in the context of our current understandings of the composition of human body and of the space-time realm. The steps involved in the process of teleportation would have to be (a) the conversion of matter (that the body is composed of) into some form of energy, (b) sending this energy in the form of radiation to its destination and then (c) reconstituting the energy back into its original material form. The students get an opportunity to calculate the required parameters and to observe the complexities and challenges involved in these steps due to our current technological limitations. Time travel on the other hand is currently more in the realm of theoretical possibilities. The unit reviews contemporary ideas that may become the basis of time travel some time in the future.

Motivation

Over the last five years I have learned many interesting lessons from my junior and senior high school students. The two that stand out among them are (a) most students perform to teacher expectations: the lower the expectation, the lower the performance; and (b) lack of student interest in the subject matter is usually indicative of a lack of challenge in the content or the way it is being taught. My motivation understandably is to make the subject I teach as challenging as I possibly can and expect that my students will rise to the occasion.

I happen to agree with those who say that science education in the United States is suffering because of its emphasis on breadth instead of depth. Students are expected to know a little about a lot of topics and as a result they end up treating the subject as no more than a big glossary of foreign terms. In writing this unit I have tried to provide my students with opportunities to study the proposed topic in a considerable depth. At the same time, the overall unit attempts to illustrate an underlying link among several topics covered in eighth and ninth grade science.

In essence, my goal was to write a unit that will provide my students ample opportunities to apply their creative skills, let them feel challenged, and force them to think through and integrate the concepts they have been learning in bits and pieces. It is my hope that provided enough examples, the students will eventually learn two important lessons: (a) real life problems are unique in nature and (b) a number of them can be solved by applying skills learned in the classroom.

Students

Although I plan to use this unit as a part of my regular curriculum it can also be used as enrichment/supplement to a number of science subjects including general and physical sciences, physics, chemistry, and biology. Specifically, I will be teaching this unit once a week (30 to 36 hours altogether) to three groups of eighth graders of varying interests and skill levels.

Strategy

To introduce my unit, I plan to address the different manipulations of time as shown in some popular movies such as *Time Bounce, Groundhog Day,* and *Back to the Future* with a partial screening of some of them. Students are expected to write a daily journal addressing major issues discussed in the class. We should be starting every class with a discussion of some of the journal entries from the previous week. Each subtopic has at least one journal entry that helps me assess students' current understanding of new concepts. For their weekly assignments, they solve problems that are applications of theory to real life. Examples of such problems are (a) time needed to travel to the nearest star at different speeds, (b) difference in the age of the twin who stayed behind in the 'twin paradox,' (c) time dilation at 90% speed of light. And finally, instead of a term paper, the students write a play based upon at least one concept learned in the class. The entire class is encouraged to participate in this play.

TRAVEL AND TRANSPORTATION

The Past and the Present

While no one is sure why we need to be always in a hurry to get from here to there, there is a general agreement that there has been a constant evolution in the methods or modes of transportation. The driving force behind this evolution has been of course, **the speed**. Once solely dependent on our bare feet, we slowly learned to ride animal backs. Animal driven carts replaced animal-back riding at some point and remained the most common means of transportation for hundreds of years. These carts became obsolete themselves as we learned to harness the power of hydrocarbons in running our cars, trains, and commercial jetliners.

During the second half of the last century, use of rockets opened up the possibilities of a much faster mode of transportation. This new mode was initially thought to have the potential to take us places well beyond our own planet. Our short life spans combined with the enormous distances to the nearby planets and stars however quickly made us realize that even rockets traveling at speeds in excess of 30,000 miles an hour aren't fast enough!

The Future

As unfortunate as they may be, our limited life spans have forced some of us to begin thinking of various exotic (wishful thinking to some) forms of travel; more common among them being teleportation and time travel. Interestingly, such trips or flights of fancy have raised some very important questions. For example, if it did become possible one day to travel back or ahead in time, how would our presence in and interaction with the past events affect our current lives (Krauss)? A number of people have raised the question about a person visiting his parents in the time before he was born and somehow ending up killing one of the parents. Does this mean that this person ceases to exist in the present time too? I think this will be a great topic for my students to write a journal entry on.

Limitations of human modes of transportation aside, there are certain things we are aware of that travel much faster than the fastest rockets e.g., voice over telephone wires, TV and radio signals, and of course the instant messages on services such as America Online. The main difference between the two is in what is moving—matter or energy? People and their belongings are matter whereas TV and radio signals are energy. Obviously, energy—in the form of radiation for wireless signals and as electrical pulses for signals over wires—travels much faster than matter: thousands of times faster.

Teleportation, as portrayed in fiction (such as the Star Trek series) appears to be a double conversion of matter and energy. Matter is converted to energy at the point of departure whereas energy is converted back to its original material form at the destination. The distance between the two points is covered in the form of radiation energy, very similar to radio transmission. The idea itself is quite creative but to verify its feasibility one needs to understand the composition of matter as well as the laws governing the matter-energy conversions. An equally intriguing possibility happens to be the application of a Wormhole or some other exotic manipulation of space-time continuum to achieve a much-desired quantum jump in the speed of travel.

COMPOSITION OF MATTER

Understanding the challenges involved in the process of teleportation requires a crash course in the composition of matter and an understanding of the relationship between energy and matter. Luckily, these topics are part of junior and senior high school curriculum as well. Students participating in my unit would only get a more interactive treatment of these topics.

Our current understanding of the composition of matter can be summarized in the next few paragraphs. All matter is composed of atoms, in other words atoms are the building blocks of all matter. Atoms are so small to be seen with our eyes or microscopes that until recently scientists only had an indirect evidence of their existence. All atoms share some common properties. For instance, their identity is determined by even smaller particles known as protons. Protons carry a positive electrical charge and reside in the central core of the atom. This central core usually houses some uncharged particles as well—neutrons, similar in mass and size to the protons.

Another type of particles called electrons (responsible for the flow of electric current) orbit around the central core of the atom. For example, Hydrogen has one proton and one electron and Nitrogen has seven protons and seven electrons. Electrons are approximately 2000 times less massive than the protons and are negatively charged. Since there is only one electron for every proton in an atom, the central core carries most of the mass of the atom. Electromagnetic forces (attraction of opposite charges in this case) keep electrons from flying away from the core. Interestingly, the forces holding the protons and neutrons together are even stronger than the electromagnetic forces. There are other smaller particles that protons and neutrons are made of that could be mentioned here. However, I have tried to stay with the most essential details in order to strike a balance between knowledge and imagination and to complete the unit within 30 to 36 weeks as well.

Atoms usually bond with other atoms to form molecules either by sharing or by transferring electrons that are the farthest from the central core. Such molecular bonds are formed between both similar as well as different kinds of atoms. For instance, Hydrogen gas occurs in its natural form as H_2—a molecule made up of two Hydrogen atoms. A water molecule H_2O, on the other hand, is made up of three atoms: two Hydrogens, and one Oxygen. Most matter, including human beings, occurs in its molecular form and not as atoms.

The above mentioned information on atomic structure is explained quite adequately in most science books written for junior high students, including the eighth grade *Science Explorer* by Prentice-Hall. Students are allowed to explore some interactive websites at this stage to review and practice their newly acquired knowledge e.g. at NASA's *Genesis* website. Immediately following these exercises, I plan to share with my students the increasing complexity in the structure of matter as one starts comparing simple gas molecules to the molecules associated with life i.e. moving from hydrogen to hydro-carbons to proteins. Most secondary science texts carry a representation of how some of these would look. There are also numerous websites with models of both simple and complicated molecules. Getting to these websites is only a matter of using a search engine like the one at google.com.

Since most students have at least a basic idea of cells, tissues, organs, and their place in the human body, I think the stage is now set for letting them see the entire picture i.e. from atoms to molecules to the cell nucleus, the cell itself and so on, all the way to the human body. There is a simple but clear diagram on the *Dummies* website. I am thinking about asking my students to draw a large diagram using this idea and posting it on the wall so we can always refer to it whenever there is any confusion about the place of atoms or molecules in the scheme of things.

Some teachers may feel that it is important to spend some time here on the structure of DNA, its significance, and our current level of understanding. The basic idea behind introducing DNA is to allow students to see that each cell in every organ of our body carries a code on the composition and function of that organ. In addition, there are differences in this code not only among different organs but also among different people. In essence the code on our DNA makes us who we are and how we appear. I recommend the book *DNA: The Secret of Life* by James Watson. This book narrates both the history as well as the science behind the DNA research.

CONVERSION OF MATTER INTO ENERGY

Albert Einstein, in his famous equation described the relation between energy and matter as: $\mathbf{E=mc^2}$. According to this equation a tiny mass of matter, when converted completely, will yield an enormous amount of energy. This is exactly the basis for the incredible amount of energy generated in nuclear power plants at the cost of so little matter. Of course, the same process, when uncontrolled, is responsible for the destructive powers of atomic bombs.

Students are encouraged to complete a reading assignment on Einstein and his contributions towards our current understanding of nature. There are several books available online that my students can use. Some of these are available through the online library our school subscribes to. The life of Einstein—his struggles at the school, his use of spare time at the patent office, and the time it took for his theories to be accepted—are all great stories that can inspire many of the students.

Students are asked to estimate the amount of energy that will be produced by converting lets say, a gram (or even 50 kilograms) of mass completely into energy. Their answers will obviously be some incredible amounts, probably a one followed by 23 or 28 zeroes. A good way for students to make sense is to compare these numbers to the energies produced in nuclear power plants or in atomic bombs. What is also important at this stage is to remind students that in the process of teleportation such immense energies will correspond to similarly immense powers since power is energy per unit time. Unfortunately, we don't have the luxury of spreading this energy over an extended period of time (it would be hard to find volunteers who might agree to be teleported bit by bit).

Students are justified in asking at this point if this conversion of matter into energy will not cause an irreparable damage to the object being teleported. As a matter of fact, Lawrence Krauss, in his book *The Physics of Star Trek*, addresses exactly this type of question (Krauss). Krauss argues about the kind of energies we may encounter in the conversion of matter and if anything could survive the process.

Krauss discusses some other interesting issues as well, such as the kind of transfer teleportation would need to be. Would it be similar to the working of the Internet, specifically, a web page that can be accessed by a number of people after the author puts the information on the server? The author's work never leaves the server but everyone gets an image of what is on it. It is possible because we are able to make a copy of it from the information that is available through the server to our computer. Would it become possible (in the case of teleportation) to just send the information (such as the DNA) over to the destination, once the matter has been completely converted to energy and expect the receivers to use their own supply of matter and reconstitute the person from the information that arrives?

Students may find it interesting to discuss as to whether we are a sum total of our parts or there is something more to us. They should think about a pair of identical twins, physically identical at birth, raised in a very similar environment and thus having very similar experiences. What sets them apart as individuals, having their own thoughts, and using their own judgments in making decisions?

Unfortunately, there is no available research on human clones yet. We do not know how clones will act—as individuals or as copies of the same person. If it turns out that they are the same person in multiple bodies, we may not need to teleport an entire person. A few cells from his or her body should suffice. Some people may argue along similar lines that if it did become possible one day to reconstitute a person from the dematerialized energy, why even send a cell through the teleporter, just send the information about the DNA, electronically!

The students need to be reminded at this stage, before we move on to the topic of time travel, that presently we are unable to "teleport" even something as simple as a Hydrogen molecule. We don't have a teleporter yet! However, we are ready for an interesting journal entry.

Potential for Problems

Students write a story about a teleportation experiment that went wrong. Since scientists have not yet been able to preserve thoughts and memories correctly during the encoding process, two scientists who used the teleportation device have their identities mixed up on a trip to Pluto. The person who thinks she is Mrs. Jackson, the NASA scientist—a 40-year-old mother of two, realizes that she has the body of Oscar—the 25-year-old graduate student from University of Houston, and vice versa. The students will describe some events during the first few days of this mishap illustrating how the two (and their respective families and friends) cope with this seemingly absurd reality. They may also want to write down some ideas NASA scientists are trying in order to remedy the situation.

TIME TRAVEL

People in general are fascinated by the idea of time travel as is evident from the popularity of movies on this topic. There must be as many reasons for this fascination as there are people. Some may want to go back to address their mistakes and fix things they did not do right the first time. Others may just want their present changed by changing the past. Yet others would like to see the future before it unfolds out of curiosity, a hope of material gain or both. In my opinion, all these desires are a manifestation of our limited life spans. Traveling in time may just provide the longevity that is currently missing.

The three movies that I plan to partially screen with my students are *Back to the Future, Time Bounce,* and selected scenes from *Star Trek* that deal with time travel and teleportation. *Back to the Future*, in which Michael J. Fox visits his parents and grandparents, provides enough points of discussion regarding the impact of such travels on the present lives of the travelers. *Time bounce* is the story of a group of people who are victims of a bizarre occurrence at a supercollider site, which causes the day to repeat itself as the machine is fired for the first time. Interestingly, no one seems to be aware of this repetition except for one plant employee who accidentally receives an electric shock at the precise moment of the firing of the supercollider and tries to stop this time loop. If time permits, I may also show snippets from the movie *Groundhog Day*, which is based on the idea of time-loops as well. I am curious to find out which one of these two movies my students rate as having a better scientific explanation. Both of them though raise an interesting question for the class to think about: Are we sure that the time bounce is not happening right now? I think this is a good time for the following two journal entries.

A Trip to the Year 1900

Students write an entry along the following lines. With the success of a particular model of time machines, people have been routinely taking trips to their past and future. Describe your experiences from a journey to the year 1900. Let us say you were visiting your great-grandparents. Write about their daily lives in the absence of television, telephones, and cars.

Time Bounce Revisited

Students are encouraged to write an entry about a day in the life of a teenager who is struggling to decide upon a friendship his mom wants him to break up that he would otherwise keep. The day repeats for him over and over until he is able to make the final decision. You may include as many characters in the story as you want.

TIME MACHINES

Some basic ideas from both general as well as special relativity need to be introduced in order to understand the current scientific basis of time travel. I plan to discuss two different kinds of time machines that may some day become practical. The first one uses the concept of wormholes and the second applies the idea of time dilation at speeds comparable to that of light.

Curvature of Space and Wormholes

Einstein theorized that the space is not always composed of straight lines. It curves near massive objects due to gravity. Although simplistic, an often-used analogy is that of describing space as a sheet of a non-rigid material like cloth or rubber held on the sides so it shows no sag. The sheet appears flat only in the absence of anything massive in the center but as soon as we place an object (of sufficient mass) on the sheet, it sags or curves around the mass: the larger the mass, the bigger the sag. There is a very simple demonstration for this analogy. Ask two of your students to stand facing each other and hold the four corners of a paper towel one in each hand so the towel is spread without a sag. Ask a third student to place a 200-gram mass in the middle. No matter how hard the students try to hold the paper towel straight, the 200-gram would always be sagging the towel.

There are several special cases on the size and geometry of the mass at the center. For example, an object of considerable mass may be able to cause a sag in the space so severe that anything that gets trapped in this sag may forever stay there. That is exactly the case with black holes—objects so massive that they are able to swallow anything that gets close to them. The reason black holes are named as such has to do with the fact that they are able to trap even the light. And since we can only see things that reflect (or emit) light, black holes are virtually invisible.

A situation somewhat similar to the black holes is known as a wormhole (Thorne). The severe curvature of space is indeed there but instead of this curvature being around a point it is formed around a line. An intriguing feature of a wormhole is that in some cases, there is believed to be a way out on the other side—to whatever region of space or time the overall curvature of this entity is connected to. An hourglass may be a simplistic way to represent such a shape. Obviously, if the other opening of the wormhole is connected to a space-time region from the past, it may be quite possible to travel to the past and the wormholes may very well become our time machines. These anomalies (wormholes) are said to exist in the space but no one has any practical ideas about designing a localized version here on the earth, yet.

Past or Future

About the time the topic of the time machine is introduced, students should have already made a couple of related entries. The first one goes something like this: Suppose you meet a scientist who claims to have invented the time machine. Volunteers are offered a trip into any period of time. The scientist has not perfected the mechanism for returning back to the present. Write a story about two groups of people who accepted the offer. One group decided to visit 50 years in the past, the other 50 years in the future. Include the city or town they are visiting, people they meet, and the kind of challenges or adventures they experienced.

Who Should Travel to the Future

A time machine has been successfully tested for the trips to the past. Scientists have just finished on the model that can take them to the future, the year 2100 to be exact. Their request for volunteers draws an enormous number of ordinary citizens. If you happen to be on the selection committee, what would be your selection criteria (age group, education, skills, etc.) for this mission?

The Sowing Down of Time

While driving to work or school, we casually observe that cars and things moving in the same direction appear to be moving slower and ones moving in the direction opposite to our car appear faster. Interestingly enough and contrary to such common observation on speeds of objects moving relative to each other, Einstein proposed the (now accepted) idea that the speed of light remains the same in all frames of reference. Which means that even in the extreme case of two observers traveling in directions opposite to each other, both at the speed of light, will only see the other one moving at precisely the speed of light and not twice the speed. Quite expectedly, a whole new set of rules had to be written due to this requirement of the speed of light being a constant. This set of rules forms the basis of the special theory of relativity.

To incorporate this constant nature of the speed of light into existing laws of nature, the observed length, mass, and time would have to change. These special rules known as Lorentz transformations, provide ways of calculating the changes in length, mass, and time for objects traveling at relative speeds. In general, the faster the speed, the greater the distortion. In this unit, I will limit the discussion to the changes in time. Specifically, the time slows down at speeds approaching the speed of light. A person traveling at speeds comparable to that of light sees a slowing down of clocks that are at rest.

The Twin Paradox

It is a hypothetical situation involving twins. It goes like this: One of a pair of twins sets out on a journey into the space at the speed of light. He travels for a while, then turns around and returns to the earth. Assuming it took him seven years to complete the trip, to his surprise he finds that his twin brother has aged twice as fast. The time was moving much slower for the twin who was traveling at high speeds.

Interestingly, the twin paradox just happens to be a unique way to travel in time (traveling to the future to be more specific.) I am not sure however, if too many people may want to go on this journey. It will be ironic if you found yourself in the future, your desired period of time but are unable to go back to the time you came from. And you may indeed want to go back when you are told of all the interesting events you missed on your way to the future.

Time Dilation: A Sentence?

Consider the case of a person who has committed a serious crime, has been convicted, and is now facing up to 14 years in prison. During the sentencing phase of the trial, his lawyer asks him if he would be interested in a mission for NASA. The round trip journey means being in the space for the next seven years traveling at a speed close to the speed of light but when he returns it would be 14 years from the time he had left. Write about the arguments the lawyer will be making in front of the jury about the seven-year mission being the same as a 14-year sentence for the convict.

A FINAL WORD

The unit allows the teachers to explore an interesting topic in substantial depth in a problem solving and interactive format instead of an emphasis on memorizing of facts. The teaching of this unit however, does involve a substantial amount of preparation on the part of the teacher.

“Imagination is more important than knowledge.” -Albert Einstein

LESSON PLANS

Lesson Plan 1: The Speed

Objective
Students analyze various modes of transportation that are available today along with some specific kinds of radiation.

Purpose
This lesson allows students to discuss the steady improvements in speeds of travel mankind has been able to achieve. Students not only see the vast differences in speeds of various modes of transportation graphically but also get to work out simple distance-time problems. The problem in this case is the time required to travel from Houston to Dallas.

Activities
Students calculate the time required to travel from Houston to Dallas, roughly 240 miles, for the following cases using the equation:

Time = Distance/Speed

Mode	**Speed**
On foot	5 mph
Horse driven cart	10 mph
Car	60 mph
Airplane	400 mph
Rocket	20,000 mph
Sound	750 mph
Light	669,600,000 mph

Materials
Calculators, transparencies, and overhead projector.

Discussion
Students discuss inventions with probing questions such as:

(a) What do you think is the greatest inventions of all times?
(b) What drives inventions?

Assessment/Independent practice
The distance between Hobby and Bush airports is approximately 25 miles. If you live near one of these airports and your workplace is near the other, what would be your preferred mode of transportation to and from work and why? Consider different times of day, different number of passengers in the vehicle, the time, and of course the cost.

Lesson Plan 2: Energies

Objective
Students are asked to draw a graph of the energies involved in given situations.

Purpose
Students get an opportunity to compare orders of magnitudes of energies involved in certain cases.

Activities

Students compare some typical energies encountered in *daily life* such as:

a) Kinetic energy of a moving car.
b) Energy that keeps two H atoms together as a molecule.
c) Kinetic energy of a speeding bullet and a freight train.
d) Thermal energy of a liter of boiling water.
e) Fission energy (per second) in a 1000 MW nuclear reactor.

Since the range of energies is so large, you may want each student group to prepare a special graph sheet themselves. Here is one idea: Take a 30x20 inch sheet of paper. Draw about twenty-five horizontal lines about an inch apart. Label each line with an energy scale that is ten times higher than the adjacent one as 1, 10, 100, and so on. You may want to draw one vertical line in the middle that has ten ticks on it dividing each energy level into ten. Your customized graph sheet is ready.

Materials

Graph sheets, map pencils, access to the Internet.

Discussion

Students discuss the enormity of the energies (fission energy) involved in the conversion of matter to energy and compare them to those of boiling water and moving car.

Independent practice

Provide students with simple equations for calculating energies in different situations, you may use the situations used in the activities above. These equations can be found in most handbooks of physics. Ask students to calculate the energies by plugging in given parameters in the equations. A number of students will need help with the use of scientific calculator.

Lesson Plan 3: Time Machines

Objective

Compare and contrast the various mechanisms shown in the clips to travel back and forth in time.

Purpose

Students are asked to watch and critique the movies not as a passive audience but in an analytical way.

Activities

After watching selected portions of the three movies, compare and contrast the different ways characters have been able to travel back in time.

Movie	Time machine	Pros/cons
Back to the Future	__	__
Back to the Future III	__	__
Star Trek	__	__
Time Bounce	__	__
Groundhog Day	__	__

Complete and discuss journal entries on:
Why do people want to go back in time?
Why do people want to travel into the future?

Materials

Selected movies, VCR, notebooks, and overhead or chalkboard.

Discussion

Students discuss the various reasons they would like to travel in time.

ANNOTATED BIBLIOGRAPHY

Books and Websites

Al-Khalili, J. S. *Black Holes, Worm Holes, and Time Machines*. Institute of Physics, 2000.
A discussion of space, time, and time machines in an attempt to understand Einstein's view of the Universe. A very well-written book aimed at junior high to school students and for people with little background in science.

A Public Outreach Module: Atoms, Elements, and Isotopes. NASA. 17 June 2003. <http://www.genesismission.org/science/mod2_aei/>.
NASA's genesis website is full of reference material. There are several interactive programs for those interested in astronomy.

Balkwill, F. and M. Rolph. *Have a Nice DNA*. Cold Spring Harbor, 2002.
An exploration of the world of cells, proteins, and DNA in a simple but accurate way. Good introductory reference for junior high students.

Eighth grade *Science Explorer*. Prentice-Hall, 2002.
An adequate description of the atomic structure and the properties of atoms for the teaching of this unit.

Krauss, L. *The Physics of Star Trek.* Harper Collins Publishers, 1995.

Most impressive book on the scientific explanations and arguments behind the futuristic Star Trek TV series. In my opinion, this book should be used as fun reading in all science classes.

Thorne, K. S. and F. Seitz. *Black Holes and Time Warps: Einstein's outrageous legacy.* W. W. Norton & Co., 1995.
The authors have done a great job of explaining complicated topics such as black holes and wormholes to people who are not experts in mathematics or physics.

Watson, J. and A. Berry. *DNA: The Secret of Life.* Knopf Publishing Group, 2003.
The science and the history of DNA research explained without using any mathematics. The book becomes very interesting as you continue reading beyond the first few pages.

Clark, R. W. *Einstein: The Life and Times*. Avon Publishing, 1999.
This is a well-written biography of a great scientific genius. Clark nicely conveys the story of Einstein's journey through physics and the personal life of a man who pretty much dominated 20th century physics. Clark, not a physics educator, actually does a marvelous job of explaining the concepts that Einstein was responsible for in his life work. I think the teachers will benefit from this book as much as their students.

Other Resources

The Discovery Channel has numerous online lesson plans, including several on DNA such as the one at <http://school.discovery.com/lessonplans/programs/modeldna/>. It addresses the questions on the relationship between chromosomes and genes and between genes and the DNA molecules.

Einstein Revealed. 1996. WBGH. June 2003. <http://www.pbs.org/wgbh/nova/einstein/>.
The website has additional teaching resources, shockwave demonstrations, and animations of relativity concepts.

Imagine the Universe! 1997-2003. NASA. June 2003. <http://imagine.gsfc.nasa.gov/index.html>.
NASA's *Imagine the Universe* website has some very interesting material for students age 12 and up, and for anyone interested in learning about the universe.