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The Plausibility of Interstellar Communication and Related Phenomena Depicted in Science Fiction Literature and in the Movies

Curriculum Unit 98.06.02
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Contents of the Curriculum Unit

The Purpose and Philosophy of the Unit

The purpose of this curriculum, The Plausibility of Interstellar Communication and Related Phenomena Depicted in Science Fiction Literature and the Movies, has four major objectives: first, to educate students to develop concepts about the proximity of our solar system in relation to other probable solar systems in the Milky Way Galaxy; second, to give students the opportunity to use these concepts to evaluate the plausibility of interstellar communication depicted in science fiction literature and movies; and third, to create an opportunity for students not only to look out on the universe but to turn it inward to look at the world, their own society, and themselves as individuals. A fourth objective that will be integrated with all of the others is to give students to opportunity to learn and/or sharpen skills in: using the scientific method, research, reading, writing, collaboration, discussion, and in critical thinking.

This curriculum is designed to serve at-risk high school students who have been unsuccessful in getting credit in a large urban high school. While it introduces several scientific concepts, it is designed to be taught by an English teacher. Therefore, it attempts to combine science and humanities, including two art projects that conclude the curriculum. In my school, the Wilbur Cross Annex, where we spend fifty percent of every day engaged in interdisciplinary team teaching, it will be possible to combine my curriculum with the curriculum in this publication written by a math teacher, Saundra Stephenson, with whom I team teach at the Annex.

This curriculum contains three specific lesson plans. One is designed to teach students concepts such as the speed of light and what the term "light year" means; another plan is designed to teach the students how to use the standard five-paragraph essay to communicate their findings after they have applied the scientific method to analyze the scientific "facts" in a science fiction short story; and third, is an exercise in the imagination, designed to encourage students to collaborate on a description of our world or society that they would send (if it were possible) into the cosmos to extraterrestrial civilizations, followed by a similar activity in which they devise a description of themselves as individuals that they would send into the cosmos. These last lesson plans lend themselves to brainstorming and collaborating and arriving at substantive answers to the questions, "What is an accurate description of us as a society or a world?" and "What is an accurate description of me as an individual?"

A Strategy for Introducing the Unit

In order to stimulate interest and curiosity among the students for the curriculum, it might be engaging to talk about whether they believe in UFO's and their belief in visitations from extraterrestrial intelligence. Citing popular movies and even showing excerpts from science fiction movies such as E.T., CONTACT, LOST IN SPACE, or MEN IN BLACK would stimulate discussion and even debate regarding whether they believe we have been visited by extraterrestrial life, or how capable they think we are of traveling to other planets outside our own solar system. Students could collaborate on a list of assumptions that each movie excerpt makes regarding interstellar communication. For example: In a scene in MEN IN BLACK a flying saucer crash lands in a farmyard, (farmyards are popular for space ship landings). From this assumption that a space ship could crash land in a farmyard, students should be able to identify questions that they need to answer in order actually to know what is feasible or plausible in interstellar communication. For example, "Just what kind of distances are we looking at when we contemplate being visited by or visiting an extraterrestrial civilization? Is it plausible that a space ship or flying saucer could crash land in a farmyard or anywhere else on earth? Does any other intelligence know we are here? How would they know? Is there any other intelligence out there?

To explore what is plausible in interstellar communication, it will be necessary to study scientific facts such as the distance between our solar system and other potential star systems in the Milky Way Galaxy that might contain intelligent civilizations, and the laws of nature regarding the speed of light and the concept of a light year. It will also be useful to study the Drake Equation, which focuses on factors, which determine how many intelligent, communicating civilizations there may be in the Milky Way Galaxy. Students will need to have at least nominal knowledge about radio waves as a means of interstellar communication.

Armed with an understanding of this information, students should be able to draw some conclusions regarding the plausibility of space travel between cosmic civilizations and to consider the plausibility of radio communications between these civilizations. Once the students have this basic working knowledge of these phenomena they will be equipped to tackle a representation of science fiction literature and movies, evaluating to some degree their plausibility, and in learning the evaluation process, actually put to use the astronomical concepts they have learned. It would be interesting to go back to the movie excerpts first shown at the outset of the unit and, given the new information, ask students to evaluate the plausibility of the premise in these movies. Students should be able to give a better informed answer to the question, "Just how 'far out' are science fiction literature and movies that deal with the topic of interstellar communication?"

When introducing the unit, students will view at least two movie excerpts or one entire movie and answer as many of the following questions (and any others you may add) as apply to the movie:

1. What kind of space travel is used in the movie?
2. If we are being visited by an extraterrestrial civilization, how did they discover that the earth has intelligent life?
3. If we are traveling to another planet outside our solar system, how did we discover it? How far away is it?
4. How long does it take us to get there?
5. What do extraterrestrial creatures look like?
6. What language or means of "talking" do they use?
7. Do they breathe oxygen or something else?
8. Are they more or less advanced than we?
9. Are they friendly or hostile? (How can you tell?)

Once students have answered the questions based on the movie or excerpts, present them with another set of questions:

1. How plausible is it that we have been located by another intelligent civilization?
2. How would they locate us?
3. How plausible that we have been visited by another intelligent civilization?
4. How would they travel to us? How long would it take?
5. How feasible is it that we have located another intelligent civilization in our Milky Way Galaxy?
6. How plausible is it for us to travel in space to reach our neighbors in another solar system in our Milky Way Galaxy, considering distances and the maximum speed we can travel?
7. What is the maximum speed we can travel?
8. Would intelligent life that visits us be more or less advanced than we are? How do you know?

The overriding question that we will focus on is: Which assumptions made by science fiction movies and science fiction literature are feasible given a few basic scientific facts and one or two basic laws of nature?

Terms that the students will need to know initially are: terrestrial, extraterrestrial, exobiology, evolution, plausible, feasible, solar system, Milky Way Galaxy, stellar, interstellar, protostar, nova, supernova, white dwarf, red star, binary system.

Distances in the Milky Way Galaxy

Distances are perhaps the most illuminating of scientific facts when pondering the plausibility of space travel, both the prospect of visiting another solar system and the prospect of being visited by extraterrestrial life. Beginning with our own solar system, students might look at the distance between our earth and the sun, which is 93,000,000 miles or eight light minutes. A light year is defined by the distance light travels in a year. The students can figure the distance represented by a light year by using a calculator and working with the fact that light travels 186,300 miles per second. By multiplying it out: 186,300 X 60 seconds, X 60 minutes, X 24 hours, X 365 days, they will come up with something in the neighborhood of 6 trillion miles, representing the distance light travels in one year.

That won't mean much to my students until I tell them that the Milky Way Galaxy, which is home to our solar system, is 100,000 light years in diameter. That is, traveling at the speed of light, or six trillion miles per year, it would take 100,000 years to cross from one edge of the Milky Way Galaxy to the other. If the Milky Way Galaxy were the size of the North American Continent, (that is the United States and Canada combined) our solar system (the sun and its nine planets) would be the size of a coffee saucer somewhere in the state of Utah. Perhaps the best way to visualize the Milky Way Galaxy is to imagine a somewhat flattened pinwheel. Our solar system is located on one of the arms of the wheel about 30,000 light years from the center of the Galaxy. In other words, if we were to choose to travel to the center of the Milky Way Galaxy, it would take 30,000 years, traveling at the speed of light to get there. Of course we do not have the technology to travel at this speed.

It might be engaging to invite the students who like to draw, or everyone, to look at some pictures of the Milky Way Galaxy in its "pinwheel" configuration and to do their own drawing of it, locating us literally as a pin prick on one of the arms, about 30,000 light years from the center. Students can observe from simulations of the Milky Way Galaxy in pictures that the center of the Galaxy or pinwheel is an intensely bright, dense bulge made up of old stars rotating out to about 20,000 light years. From this bulge the arms of the pinwheel spiral outward.

According to the laws of nature, nothing travels faster than the speed of light. So there is no faster way to cover the distances in space. And, the laws of nature do not change in other parts of the universe; they are the same throughout. Whether we are traveling to another planet or we are being visited by extraterrestrial intelligence, the distances cannot be covered any faster than 186,300 miles per second. And of course at present, we have not mastered travel at these speeds. But, suppose it were possible. How far away are other suns that are the center of solar systems that have accompanying planets that might harbor intelligent life?

Star Types Capable of Sustaining Intelligent Life

To answer this question, we must first look at the kinds of stars like our own sun known as a G star that have characteristics like our sun that can sustain life on an accompanying planet long enough for it to evolve into intelligent life and perhaps a communicating civilization. Not all stars have sun-like characteristics that would be capable of sustaining terrestrial life to the point of intelligence. Some, such as luminous blue stars, due to their mass which is much larger than our sun, burn hydrogen so rapidly that they will burn out and explode as supernovae before life on an accompanying planet has a chance to evolve to terrestrial intelligence.

All stars go through several phases in their evolution. First, each is a protostar, a gravitationally stable cloud of stellar mass contracting in an early pre-main-sequence state. In this stage, the protostar has a low temperature, a high luminosity because it has a large radius. Next, it contracts rather rapidly through the pre-main sequence and in about a million years reaches the main sequence. The length of time a star remains in the main sequence and how it plays out its life is determined by its mass. Our sun, a G star will remain in the main sequence for about 10 billion years. This provides plenty of time for life to evolve to a highly intelligent, communicating civilization. Then, when the hydrogen in its interior has been used up, the outer layers of the star will expand, and the star will become much larger in radius, moving out of the main sequence stage. At this point it will be called a red giant. At this stage, the earth will heat to the extent that all living things will perish, all water will boil and evaporate, and essentially the earth will burn to a cinder. Then when the combustible elements are used up, the star will contract and grow dense, ultimately reaching the size of the earth. As it evolves from a red giant to its final stage, a white dwarf, it is identified as variable or unstable. In its final stage it is called a white dwarf. The sequence for our sun, a G star is: protostar, pre-main sequence, main sequence, red giant, unstable, white dwarf.

Stars called red stars with a mass less than our sun will burn too coolly and require that an accompanying planet must orbit very closely in order to maintain the temperatures that will sustain life long enough to evolve to terrestrial intelligence.

The characteristics of the massive fast-burning luminous blues and the less massive cool-burning red stars either because of temperature or life span in the main sequence are not capable of sustaining earth-like or habitable planets. Note that students who want extra credit or who are just curious about these stars and their evolution and characteristics could investigate and report to the class their findings on: luminous blues, supernovae, binary stars, novas, white dwarfs, red stars, and G stars like our sun.

Novae and supernovae are different from each other. Novae can recur, and always are in binary stars. Supernova explosions are terminal, and may or may not be in binary systems. Neither of these characterizes our G star, the sun. It is neither a part of a binary star system nor is it a massive star that will terminate in a supernova. Our sun will never explode in its terminal evolution.

In l987-88 we observed a super nova in the Magellanic Cloud formation, a small galaxy some 130,000 light years from our solar system. Of course, given this distance, we need to keep in mind that this super nova occurred approximately 130,000 years ago, but the light from the phenomenon reached us in l987-88.

Our own sun has about 4 billion years of energy left it at which time it will swell into a red giant, probably swallowing up Mercury and "cooking" our planet earth, certainly evaporating all the water in rivers and oceans. Eventually our sun will shrink to a white dwarf and cool down.

Calculating the Probability of Intelligent Life in the Milky Way Galaxy

In l961, Frank Drake developed the Drake Equation, a rather complex calculation that indicates that intelligent life is probable in the Milky Way Galaxy, and suggests where we might look or "listen" for it. At first glance, the Drake Equation is somewhat intimidating:

$$N = N^{*}\ fp\ ne\ fl\ fi\ fe\ fL$$

But, it can be broken down so that it is manageable.

N represents the number of intelligent communicating civilizations there are in the Milky Way Galaxy.

N* represents the number of stars in the Milky Way Galaxy.

Modest estimates are between 200 - 250 billion.

fp represents the fraction of stars that have planets around them as our sun has planets around it.

Current estimates range anywhere from 20% to 50%. (Consider the types of stars that have sun-like characteristics discussed on page 5)

ne represents the number of planets per star that are capable of sustaining life.

The most modest estimate is 1.

fl is the fraction of planets in ne where life actually evolves.

Current estimates range from 100% down to 0%.

fi is the fraction of fl where intelligent life evolves.

Again, estimates range from 100% down to 0%.

fe is the fraction of fi (intelligent life) that communicate has the means and desire to communicate

Estimates range from between 10% to 20%.

fL is the fraction of the planet's life during which the communicating civilizations live.

This is the most difficult estimate because as we know from our own civilization, we could eliminate ourselves from the face of the earth with nuclear warfare, but if we survive we could be around for tens of thousands of years. This is also true of extraterrestrial civilizations.

When all the variables are multiplied, we come up with this speculation:

N, the number of communicating civilizations in the Galaxy.

The students can experiment with this formula with the following variables and then experiment with their own variables to see how many communicating civilizations they think may be out there in the Milky Way Galaxy.

N* = the number of stars in the Milky Way Galaxy: 100 billion (100 billion is a very low estimate but makes it easier to multiply)

fp = fraction of stars with planets around them: 50%

ne = the number of planets per star ecologically able to sustain life: 1%

fl = fraction of those planets where life actually evolves: 50%

fi = the fraction of fl that evolves to intelligent life: 20%

fe = the fraction of fi that tries interstellar communication: 20%

fL = the fraction of the planet's life during which the communicating civilization survives: 1/1,000,000th (10,000 years)

When the students calculate all of these variables, using these statistics based on the very low estimate of 100 billion stars in the Galaxy, they should come up with:

N = the number of communicating civilizations in the Milky Way Galaxy = 1,000

If there were 1,000 communicating civilizations in the Milky Way Galaxy, given the vast area of the galaxy (100,000 light years in diameter), the average distance between intelligent civilizations would be approximately 1,700 light years. Hence, radio signals seem to be a far more plausible means of communication than space travel.

Interstellar Communication through Radio Waves

Since the l920's our planet Earth has been broadcasting radio waves, by now reaching some 70 light years into space. In distance, this amounts to six trillion miles times 70, or 420 trillion miles. If a technical civilization existed within 70 light years from our solar system, and if it were "listening," it would have detected us. However, it would take that civilization another 70 light-years to respond with radio communication, and far longer to reach us by space ship unless it were capable of traveling at the speed of light. Therefore if an extraterrestrial civilization picked up on our 70-year-old radio waves in l998, we would not receive its response in radio waves until the year 2068.

Realistically an intelligent technical civilization is at least say 1,700 light years from our solar system which means it will take, not 140 years from the time our broadcast leaves Earth until the time the technical civilization responds, but 3,400 years. This of course does not take into account the amount of time it may take for the receiving civilization to decode the signals. Scholars worked to decode Egyptian hieroglyphics for over 100 years to no avail, until the discovery of the Rosette Stone helped translators crack the code. And this was a language devised by human beings. Decoding signals from an extraterrestrial intelligence may be far more complex.

In l974 a radio message was transmitted from the largest radio telescope in the world, Arecibo, in Puerto Rico. Some of the basic information being transmitted were images of the Arecibo radio telescope, an image of the sun and its nine planets, an image of a human form, an image of the double helix of the DNA molecule, and chemical formulae for the compounds of this molecule. This message was aimed at a globular cluster of stars known as M13 in the Milky Way Galaxy and at a distance of 30,000 light years from our solar system. What a leap of faith to expect to hear a response from this radio transmission approximately in the year 60,000 A.D.!!!!

This same radio observatory receives and analyzes radio waves from the depths of space. There are many natural cosmic radio sources such as quasars and pulsars being received. What the observatory or telescope listens for is a pattern, signals that are repeated in a systematic way, such as the prime numbers transmitted from the area of the star Vega in the movie CONTACT. When the signal was transmitting these numbers through 100, there was no mistake that interstellar communication was taking place. It is widely accepted by astronomers that mathematics may be a common language shared by all technical civilizations.

The Feasibility of Interstellar Communication and Travel in the Movie CONTACT Based on the Science Fiction Novel by Carl Sagan

In the movie CONTACT, based on the science fiction novel by Carl Sagan, the character Ellie Arroway, an astronomer who has devoted her career to listening for radio waves from extraterrestrial intelligence, received not only radio signals from an extraterrestrial civilization but an entire blueprint for building a launch mechanism and space craft for travel to that civilization. The radio signals came from the area of the star Vega, approximately 26 light years from earth, in the constellation Lyra. Traveling at the speed of light, it would take a person 52 years to travel to and from a planet orbiting Vega. With the means of travel sent in the blueprint, traveling at the speed of light may have been possible. At the moment of the launch, observers saw Ellie's spacecraft fall through the launch mechanism and drop into the bay where she was subsequently rescued. Ellie, on the other hand, experienced traveling through space to the civilization with which she had a conversation and returned to earth.

The overriding question was, how could she possibly have traveled through space when observers saw her craft drop through the launch and into the bay where the launch had been built. Is it plausible that Ellie's craft defied some natural law and traveled through a time warp? Scientific facts tell us this is not possible. Yet, the tape on board her craft recorded 18 hours, albeit the sound of static, from the time of launch to splash down in the bay. And, in 18 hours how could she travel at the speed of light to and from an extraterrestrial civilization 26 light years away? These are some of the issues that make the book and subsequent movie CONTACT the product of science fiction.

Once the students are equipped with a basic knowledge of the limits of space travel given the laws of nature and the distances in our Milky Way Galaxy and the universe, they can analyze the plausibility of events in CONTACT. The more they know about the laws of nature and space travel and distances, the more they can interact with the facts presented in the movie. The more engaging and challenging the issues become.

The Feasibility of Space Travel and Related Phenomena in "The Rescue Party," a Science Fiction Short Story by Arthur Clarke

In the highly engaging science fiction short story, "The Rescue Party" by Arthur Clarke, our planet earth is about to be obliterated by the sun, which is about to explode in a nova in approximately seven hours. An extraterrestrial intelligence is approaching the earth in a space ship with the hope of rescuing at least a few hundred of its inhabitants before this obliteration takes place. They are racing against time, hoping to land and complete their rescue while the sun is in its pre-nova stage.

The main space ship covers one billion miles in a few hours and deploys two explorer modules to descend to the earth's surface. The description of the earth at the time of pre-nova and these landings and explorations is very dramatic and replete with Armageddon-like imagery. It is discovered that the inhabitants of earth are no longer there, or they have burrowed so deeply into its interior that they cannot be detected. But in the process, one of the rescue parties becomes caught in an underground subway train, and is on its way under one of the oceans where there will be no chance of rescuing the team. The tension mounts when a decision must be made as to whether there is time to rescue the rescue party and escape the nova.

The students, knowing the distance that can be covered by the speed of light, will be able to calculate whether the space ship can cover one billion miles in "a few hours." They should be able to calculate that, in fact, it will take approximately 15 hours, traveling at the speed of light for the space ship to travel one billion miles. According to calculations in the story, the nova will occur in just seven hours. So, it is not plausible that the space ship can cover one billion miles before the sun becomes a nova in seven hours.

Also, the subway train in which the extraterrestrial rescue party is caught is heading under the ocean, making rescue within the very limited time almost impossible. Clarke describes fierce wave action, and mile high waves, sweeping over large portions of continents toward mountain ranges. While these descriptions are dramatic, and the prospect of the subway train traveling under the ocean makes rescue virtually impossible, the fact is that by the time a star were in its "pre-nova" stage about to become a "nova," the heat from the expanding star would have evaporated every last drop of water.

The students, having studied star types, will also know that our sun cannot become a nova; it would have to be a star in a binary system to become a nova. There will be no nova-like explosion as predicted in the story. In about 4 more billion years, the sun will have grown hotter and it will expand to a red giant and then shrink in size to become a white dwarf and cool to the extent that it will no longer heat the earth. But before it cools, it will become so hot in its expansion that it will evaporate all of the water from the face of the earth. So, the roiling oceans that Arthur Clarke describes in the sun's " pre-nova," while effective, engaging descriptions, are not accurate. Knowing these facts in no way detracts from the engaging power of the story but rather makes reading it a more interactive process. It gives the student the information and a process for determining for him or herself just how "far out" is science fiction.

Applying the Scientific Method to the Study of Science Fiction Literature and Movies

One method of engaging students in the learning process is through the implementation of the scientific method: identify the problem, analyzing it, solving it, and communicating your findings. This method is effective for students working independently or collaboratively. Once students have a basic knowledge of a few scientific facts and the laws of nature, including: distances in the Milky Way Galaxy, the speed of light, a light year, the probability of extraterrestrial intelligence, the evolution of stars and of our sun in particular, they can approach science fiction better informed. They can actually be on the look out for phenomena based on plausibility and that which is totally implausible given what they have learned. They can interact with the material in a new way.

An approach to the study of the movie CONTACT or the short story "The Rescue Party" might be to observe and read, asking, "Where do the science fiction "facts" seem out of context with what we have learned?" What problems does the science fiction present that are totally outside of scientific fact or the laws of nature that the students have studied? Once they have identified these inconsistencies, either independently or in collaboration with other students, they must analyze them using the facts and information they have learned. Each team of students could analyze a separate problem in an attempt to justify or disprove it. Or to add a competitive edge, each team could analyze the same problems and compare their findings. Regardless of the logistics, students must communicate their findings either in writing or in an oral presentation. My second lesson plan uses the five-paragraph essay as a vehicle for communicating the findings in "The Rescue Party."

LESSON PLAN I

The Speed of Light and its Relevance to a Light Year as a Means of Measuring Distances in the Milky Way Galaxy

OBJECTIVE: After completing this lesson, students will have an understanding of the distances covered at speed of light, and a light year, and know how to measure distances in the Milky Way Galaxy.

I. Give students a simulation or drawing of our Milky Way Galaxy, pointing out the position of our Solar System on the Orion arm of the pinwheel. (Most good astronomy books have an illustration of the Solar System located in the Milky Way Galaxy.) Ask them to take a few notes, first that we are located 30,000 light years from the center of the galaxy and that the galaxy is approximately 100,000 light years in diameter.

Ask the students if anyone has any idea how to measure the distance of a light year. Ask if anyone knows how long it would take us to get to the center or outer edge of the Milky Way Galaxy, traveling from our Solar System. Ask them to solve the mathematical word problem:

> If light travels at 186,300 miles per second, how far does
> it travel in one hour, one day, one year?

Once they have solved this problem, give them this problem:

> How far, in miles, is it to the center of the Milky Way Galaxy from our Solar System and how far it is in miles to the outer edge of our Milky Way Galaxy?
> Traveling at the speed of light, how long would it take us to get to the center and to the outer edge?

Add to their notes that the Universe has been measured at 30 billion light years in diameter, and that there are virtually thousands of galaxies out there, some larger and many smaller than ours. Add that the nearest large galaxy, Andromeda, is approximately 2 million light years away. Among the small galaxies closest to the Milky Way Galaxy are the Large and Small Magellanic Clouds, at a distance of approximately 130,000 light years.

Give them another word problem:

> If the star Vega, a bright star in the constellation Lyra, is 26 light-years away, how many miles is that?
> If you were to visit a planet circling Vega, and you could travel at the speed of light, how many years would it take you to make a return trip?
> If your best friend were 20 when you left for Vega, how old would he or she be when you returned?

II. Word problems to measure the students'understanding of distances covered at the speed of light and the concept of a light year. (They should be allowed to use their notes.)

1. The sun is 93,000,000 miles away. How much time does it take for its light to reach the earth?

2. We observed a supernova in the Large Magellanic Cloud in l987-88. When did the supernova actually occur?

3. How would you set up the calculation for finding the distance from the Milky Way Galaxy to the Andromeda Galaxy? (You don't have to find the answer.)

LESSON PLAN II

Communicating Solutions from the Scientific Method Process

OBJECTIVE: When the students complete the lesson, they will have used the formula for preparing and writing a standard five-paragraph essay.

Students will have read "The Rescue Party," identifying and analyzing implausible scientific facts and phenomena which digress from what they have learned about: (1) the life cycle of our sun, (2) distances and the speed of light, and (3) the effect that the sun will have on the earth when the sun is in its "red giant" sequence. This pre-writing activity can be recorded on a chart with PROBLEMS in the first column, ANALYSIS in the middle column, and FINDINGS or OUTCOME in the last column.

From this pre-writing activity, they will have completed the process preparing them to draw a conclusion, for example: Some of the scientific facts and phenomena in "The Rescue Party" are implausible and inaccurate. This conclusion becomes the basis for the thesis of their essay. Using this thesis, they set up the introductory paragraph of their essay, which includes four sentences: the thesis, and three controlling ideas which are taken from information on their chart.

Paragraph I (thesis) Some of the scientific facts and phenomena in the science fiction short story, "The Rescue Party," by Arthur Clarke are implausible and inaccurate. (controlling idea # 1)The urgency of events in the story is premised upon our sun exploding into a nova, a phenomenon that defies scientific fact. (controlling idea # 2) The extraterrestrial intelligence traveling to the earth to rescue at least a few hundred earthlings is traveling at speeds that defy the laws of nature. (controlling idea # 3) Descriptions of the oceans in the earth's final stages are dramatic and add a great deal to the conflict in the story, but in fact the earth's oceans will have totally dried up when the sun reaches its terminal evolution.

Paragraph II (the student repeats controlling idea # 1 as the topic sentence and, using the information from the chart, gives evidence for the topic sentence. It may be necessary to add in some background information from the story.

Paragraph III (the student repeats controlling idea # 2 as the topic sentence and, using information from the chart, gives evidence for the topic sentence. It may be necessary to add in some background information from the story.

Paragraph IV (the student repeats controlling idea # 3 as the topic sentence and, using information from the chart, gives evidence for the topic sentence. It may be necessary to add in some background information from the story.

Paragraph V (the conclusion, like the introduction has four sentences: one that resembles the thesis in the introduction, and one that makes a statement regarding each of the controlling ideas discussed in detail in paragraphs two, three, and four.

Thus, the standard five-paragraph essay has no surprises, and the student learns to treat it almost as a mathematical formula. This may not be an imaginative approach to writing an essay, but with practice, at-risk students who have never mastered a standard essay are able to grasp the formula, especially if the pre-writing activity, (a chart gives the student a sense of security), plugs into the essay. This highly structured formula gives students a dependable vehicle for communicating their findings.

This lesson works well as a class activity, taking the class through the writing process after having completed the pre-writing chart. Students hand in their first draft of the essay with the idea that they will have another opportunity to rewrite the draft for a higher score. The idea is to end up with a final draft that gives the student a sense of pride and accomplishment, especially when he or she looks back at previous drafts that are attached behind the final, best draft. The pre-writing chart should also be attached so the student can review the process.

LESSON PLAN III

Sending a Message Into Space

OBJECTIVE: After completing this lesson, students will be more aware of the way they think of the world, and/or our society, and themselves as individuals.

I. Give the students a handout explaining the radio message transmitted from Arecibo, in Puerto Rico in l974. (See p. 8 for a detailed explanation.) Read and discuss information about the transmission and the contents of the message.

Either as a class or in teams, ask the students to pretend they have been selected as a committee to brainstorm a list of images, words, phrases, symbols, sounds, etc. that they think are representative of the world or of our society today. Give them a specific amount of time to complete this activity.

Depending upon the approach you took, the class working as a whole, or in teams, assign the project through the medium of collage or some other medium, of creating an art form that the class or the teams think represents our society and would introduce us to extraterrestrial intelligence. When the project is finished, there should be one (if the class worked together), or several representations, accompanied, perhaps, by music or sounds that have been recorded. If the team approach is used, each team can present its representation to the class. The final product can be mounted in the classroom as a class statement.

II. This same activity can be implemented in which each student brainstorms images, phrases, words, symbols, sounds, etc. that represent him or herself. A representation of the brainstorm can be created through the medium of art or through any medium the student chooses and presented to the class. Again, the question guiding the project is: If you could send a representation of yourself into space to introduce yourself to an extraterrestrial civilization, how would you put it together; how would you package yourself? What best represents you?

The final products of this activity also can be mounted as statements in the classroom.

This lesson is meant to challenge students to be reflective, and to turn the telescope inward and to think about their society and about themselves as individuals.

VOCABULARY AND TERMS FOR THE UNIT

Andromeda Galaxy: the nearest spiral galaxy comparable to our own, about 2 million light years away.

Arecibo: the largest semi-steerable radio/radar observatory on Earth.

binary system: a pair of coorbiting stars.

Drake Equation: the statement that the fraction of stars harboring intelligent life equals the number of all stars times a sequence of fractions, such as the fraction of all stars having planets, the fraction of planets that are habitable, and so on. Named after the radio astronomer Frank Drake.

evolutionary theory: a theory in which changes occur by relatively slow processes commonly growing out of initial conditions.

exobiology: study of life beyond the Earth.

extraterrestrial: outside the limits of the Earth.

interstellar: situated or occurring between stars.

Large Magellanic Cloud: the larger of two galaxies nearest the Milky Way, irregular in form and visible to the naked eye in the Southern Hemisphere.

Milky Way Galaxy: the spiral galaxy in which we live.

nova: a type of suddenly bright star resulting from explosive brightening when gas is dumped from one member of a binary star pair onto the other.

protostar: a gravitationally stable cloud of stellar mass contracting in an early pre-main-sequence evolutionary state.

red giant: a post-main-sequence star whose surface layers have expanded to many solar radii and have relatively low temperatures

Small Magellanic Cloud: the smaller of two galaxies nearest the Milky Way, irregular in form and visible to the naked eye in the Southern Hemisphere.

Solar system: the Sun and all bodies orbiting around it.

stellar evolution: the evolution of a star from one form to another forced by changes in composition as nuclear reactions proceed.

supernova: a massive stellar explosion blowing off most of the star's mass, leaving a dense core.

terrestrial: pertaining to the Earth or this world.

white dwarf star: a planet-sized star of roughly solar mass and very high density produced as a terminal state after nuclear fuels have been consumed.

STUDENT READING AND VIEWING LIST

Arny, Thomas T., Explorations, An Introduction to Astronomy (St. Louis: Mosby, l996).

Begley, Sharon, Thomas Hayden, and Andrew Murr. "How Planets are Born," Newsweek, (May 4, 1998), 54 - 60.

Berman, Louis, Exploring the Cosmos (Boston: Little, Brown and Company, l973).

Clarke, Arthur C., "The Rescue Party" Great Tales of Action and

Adventure (NewYork: Dell Publishing, 1959).

Sagan, Carl, Contact (New York: Simon and Schuster, 1985).

Sagan, Carl, "Encyclopedia Galactica," Cosmos (New York: Ballentine Books, l980).

Sagan, Carl, Encyclopedia Galactica, Volume 12, the video (Carl Sagan Productions Inc., 1989).

Sagan, Carl, "The Persistence of Memory," Cosmos (New York: Ballentine Books, l980).

Sagan, Carl, The Persistence of Memory, Volume 11, the video (Carl Sagan Productions Inc., 1989).

Zemeckis, Robert, Contact. l997. Warner Brothers.

TEACHER BIBLIOGRAPHY

Abell, George, David Morrison, and Sidney Wolff, Explorations of the Universe, fifth edition (New York: Saunders College Publishing, l987).

Arny, Thomas T., Explorations, An Introduction to Astronomy (St. Louis: Mosby, l996).

Berman, Louis, Exploring the Cosmos (Boston: Little, Brown and Company, l973).

Clarke, Arthur C., "The Rescue Party," Great Tales of Action and Adventure (New York: Dell Publishing, l959).

Field, George B., The Invisible Universe (Boston: Birkhauser, l985).

Hartmann, William K., The Cosmic Voyage Through Time and Space (Belmont, California: Wadsworth Publishing Co., l992).

Sagan, Carl, Contact (New York: Simon and Schuster, l985).

Zemeckis, Robert, Contact. 1997. Warner Brothers.

Sagan, Carl, The Cosmic Connection (New York: Ballentine Books, l987).

Sagan, Carl, Cosmos (New York: Ballentine Books, l980).

Sagan, Carl, The Pale Blue Dot (New York: Random House, l994).

Sagan, Carl, "The Search for Extraterrestrial Life," Scientific American 271 (October 1994): 76.

Shostak, Seth, "Listening for Life," Astronomy 20 (October l992): 26.

Zuckerman, Ben, and Michael H. Hart (eds.) Extraterrestrials, Where Are They? (Boston: Cambridge University Press, l995).