Teaching Technology, Environment, and Thinking Skills by Using the Basic Steps of the Scientific Method

Rafael Betancourt
Middle College for Technology Careers

TEKS + TAKS → STRESS

This chain reaction represents the disease we Texas teachers are experiencing at this moment before the first Texas Assessment of Knowledge and Skills TAKS test which the students are going to take. The reaction above also represents a state of mental conditions teachers are suffering from the pressure coming from principals and coordinators because of the students' results on the TAKS. These results are very important for the students, teachers, administrators, parents, legislators, prospective employers, and the public in general.

Under the competency 003 of the Texas Examination of Educator Standards, the curriculum in the Texas public school is based on the Texas Essential Knowledge and Skills (TEKS). We Texas teachers must memorize learning standards in order to plan appropriate instructional goals and objectives every day in our classroom (TExES 43). This curriculum contains the basic content and process skills that scholars should develop in each grade level in the areas of arts, mathematics, science (biology, chemistry, and physics), social studies and citizenship, and the use of technology.

In 2003, the state of Texas developed the standard assessment of Texas Assessment of Knowledge and Skills TAKS test as the single tool to measure a student's knowledge and academic progress in different grade levels. For example, in grades four and seven, the students take the Writing Skills section of the TAKS test. In the third and ninth grades, the students are assessed in reading. English and language arts are assessed during the tenth and eleventh grade years. Mathematics is assessed in all grades from third to eleventh. However, the science section is evaluated at the fifth, tenth, and eleventh grades. Finally, the social studies section is assessed in the eighth, tenth, and eleventh grades (TExES 43). This system tries to measure the academic evolution of a student under the Texas educational system. This evaluation process measures the quality of the education in the state of Texas. However, I have noticed that the level of stress among the principals, students, and teachers in my school increased so much that it was necessary to implement a system to alleviate this tremendous pressure which we all breathe every day.

INTRODUCTION

I work for a small school located on a university campus, the Middle College for Technology Careers High School (MCTC). The school is part of Houston Independent School District (HISD) and is under the magnet program as a technological school. I am teaching ninth graders in the area of integrated physics and chemistry (IPC). I teach the most romantic subject, chemistry, to my tenth and eleventh graders. My students have selected my school for obtaining computer certification and, at the same time, a high school diploma. They work with computers and electronic devices every day in their classes. In the near future, my school will be the first public school of HISD in which every student will be assigned a laptop as part of their academic materials.

Computers and any other electronic devices are composed of electric and electronic components. Inside computers there are several parts, which enable a user to carry out any desired operation. If we break a computer apart, we will find many electronic components made of different types of materials: electric circuits, diodes, condensers, resistors, etc. We as teachers need to take advantage of all the electronic components of an old computer to help our students be aware of the possible pollution problems associated with the process of dumping old computers.

Once the computer is considered old and useless, the easiest way to get rid of it is to dump it in the trash or throw it away. The following question arises from this action: what happens when the old computer is in contact with the underground water or any other chemical substance necessary for life? We need to measure the damage the old computer might cause the environment. Furthermore, we need to think about how to develop a recycling program for electronic parts. MCTC students should develop the concept of recycling and reusing the electronic parts inside the old computer since they are part of our society.

Consequently, I plan to compose a unit dealing with the problem of computer waste—its chemical effect on the environment, the regulations and programs dealing with this problem, and a method for formulating the solutions to this problem. Furthermore, this unit will demonstrate to the students how to develop a science project, which analyzes and solves this pollution problem by using the scientific method. However, the main objective of this curriculum unit is to develop the ability of my students to investigate and research important issues related to our environment. In the closure of my unit, after the students have seen a good model of a properly completed science project, they are going to be assigned another problem related to their science classes: Chemistry, Physics, or Biology. They are going to present their own investigations using the learned method of researching scientific topics by inquiry.

UTILIZING THE SCIENTIFIC METHOD

In this unit, my students will learn how to use the scientific method – an important investigative tool on which all serious research is based. This approach to learning the scientific method will not be the traditional way of teaching or lecturing; my students are going to experience a new way of using the scientific method. First, they are going to dramatize a situation in which two students talk about an old computer. Then my students are going to break down an old computer into parts and analyze what is found inside the computer. Next they will participate in the process of making a circuit board. The waste solutions leftover from this process are going to create a serious problem: waste products. They will begin with the inquiring part of the scientific process by formulating a hypothesis, researching questions, and selecting the variables necessary to carry out individual experiments. During the phase of doing the practical work, my students will have the opportunity to evaluate and modify the procedures with the purpose of formulating suggestions according to their every day life experiences. After the raw data has been collected (quantitative data), they are going to apply their mathematical knowledge for processing and presenting the data using scientific regulations (scientific notation). My students will also be trained in the field of making reliable observations of chemical changes (qualitative data). The aspect of ethics and data integrity will be stressed since their training should include this aspect as well ("Exciting Experiments and the *Ethics* of Experimentation"). Then they will evaluate the data with the purpose of examining the problem in question and proposing possible solutions. This evaluation process is one of the most important aspects in this unit, since it demands high-level critical thinking skills. Finally, they are going to simulate how a group of employees makes a decision in buying computers for a company. This decision making process is going to be based on an environmental impact, rather than high technological issues.

THE POLITICAL PERSPECTIVE

Besides learning to solve a problem scientifically, the students will gain political insight. This insight is important because science and politics often overlap. The origin of the computer waste problem is to be found by analyzing the policies and regulations of the computer companies that manufacture these electronic devices. These companies typically look at the production and commercialization aspects, but do not consider the environmental impact of such equipment. Computer manufacturers should include a seal, which reads "Environmentally Friendly," for such equipment. This seal should signify that the equipment would not interfere with any natural cycle in our environment. My students should be aware of the process of making the decision to buy specific computers by taking into consideration the aspect of environmental problems associated with computer dumping or possible ways to recycle the old computer's electronic parts.

ESSENTIAL ELEMENTS OF CHEMISTRY

There are several experimental skills that my students will need to master for the TAKS**.** TAKS is one of the promotion standards in Texas. The TAKS test evaluates the students in two fields: content and process. In the content area there are several specific objectives in chemistry that the students are expected to learn. In the process area, the students should master several laboratory skills by carrying out practical investigations. To pass the science section of the TAKS, students must master certain skills and have a broad knowledge of science (TEKS Science Art). My students will need to develop certain scientific skills such as formulating hypotheses, selecting variables, and using equipment and technology to research any real life problem. Secondly, my students will need to evaluate scientific explanations, theories, and hypotheses by analyzing scientific evidence. Finally, they will undertake the process of evaluation of the scientific impact on the environment and society.

In the content area, my students will be required to study thermo-chemistry. They will experiment with the thermo-chemical process as exothermic and endothermic reactions in different states of matters. Another field of investigation is the physical and chemical properties of ionic and covalent compounds (*SEPUP Module Correlation*). My students are going to be exposed to a practical activity in which they will compare and contrast the properties of such compounds. Secondly, they will be equipped to work with the concepts of the oxidation-reduction process with chemical substances, which are related to the computer manufacturing industry. Also, they will simulate how these chemical processes affect the natural cycle of underground waters or water reservoirs. Next in line is the concept of corrosion of metals. They will study the factors affecting corrosion and how to prevent such a damaging chemical process. Either directly or indirectly, my students will learn scientific nomenclature and chemical terminology of chemical compounds and chemical reactions. They will be trained in writing chemical formulas, balancing chemical reactions, nuclear reactions, and redox reactions. These topics demand a higher order thinking process in line with Bloom's taxonomy. Another environmental issue common in Chemistry and Environmental Sciences is the application of acid-base theory on ecological systems. My students will simulate how a reducing agent and an oxidizing agent are harmful to the natural pH value of water and any other aqueous solutions. In synthesis, we, as science teachers, need to train our students by using specific guidelines found in the TEKS.

According to the Office of Educational Research, different studies have demonstrated that cooperative learning produces an atmosphere of achievements, the development and use of critical-thinking skills, and positive relations between teachers and students (Office of Education Research, 1992). As a consequence, my students and I will form a scientific team that will be able to investigate and experiment together. Therefore, all of these practical activities will benefit both the students and the teacher at the same time.

The experimental activities will be selected according to topics oriented toward the central goal: "To provide educational experience focusing on science and technology and their interaction with people and the environment" (*SEPUP Module Correlation*). The first practical action is based on the study of ions and electrolytes in relation to the redox reactions. The scientific team will investigate the production of toxic waste in the manufacturing of electronic circuits. The next activity will be oriented toward the study of concentrations of copper (II) ions by the dilution of copper (II) chloride ($CuCl_2$), at different concentrations. The concentration unit that will be used in this lab is the parts per million (ppm) or milligrams per liter. An alternative project to investigate would be the effect of copper (II) ions in the growing of plants in order to determine the biological impact of such solutions on flowered plants (Widger). Following this activity, the investigating team will be ready for reclaiming waste through metal replacement. In this experiment, the team will study replacement reactions by the formation of precipitates. The use of the principles of the activity series is a very important aspect to consider in the reaction activity with respect to the metals in the activity series. The following example is useful to illustrate this important concept:

$Zn_{(s)} + CuSO_{4\,(aq)} \rightarrow ZnSO_{4\,(aq)} + Cu_{(s)}$ (CHEMICAL REACTION)
$Zn^0 \rightarrow Zn^{+2} + 2e^-$ (OXIDATION -HALF EQUATION)
$Cu^{+2} + 2e^- \rightarrow Cu^0$ (REDUCTION-HALF EQUATION)

$Zn^0 + Cu^{+2} \rightarrow Zn^{+2} + Cu^0$ (NET IONIC EQUATION)

In our next activity, the investigating team will work with another concept of single and double replacement reactions of metals, still using the activity series. Metal reclamation deals with the recuperation of the most useful metals needed in certain industries that make use of electronic parts (*SEPUP Module*). Significantly important transitional metals will be considered in this activity.

In the last stage of the investigating project, the team will be working in the field of toxic waste and management. The team will investigate the chemical processes occurring at the landfills, such as fixation and leachates. The students will answer the following question: how might toxic waste chemicals contaminate underground water by the process of percolation? (*SEPUP Module*) This is the type of research question used in this investigation during the practical activity.

Another process occurring at the landfill is the incineration of electronic devices such as computers. What is the final product when a computer goes through the process of combustion? The topics to be applied in this investigation are the thermodynamic process of exothermic and endothermic reactions. We will analyze what electronic components will absorb or release heat during the combustion process. The thermodynamic formula to be used for studying such important questions is the following: $Q=\Delta H= m \cdot C \cdot (T_{final} - T_{initial})$ (Chang). Where m is the mass of the object and C is the specific heat capacity. The team will investigate the different heat capacities of electronic materials. Then the team will calculate the amount of heat released or absorbed during the incineration.

The last experiment in this project is sorting the electronics parts as recyclable and reusable for future use or not. The team will determine the properties for an electronic part to be considered as fit for any of these categories.

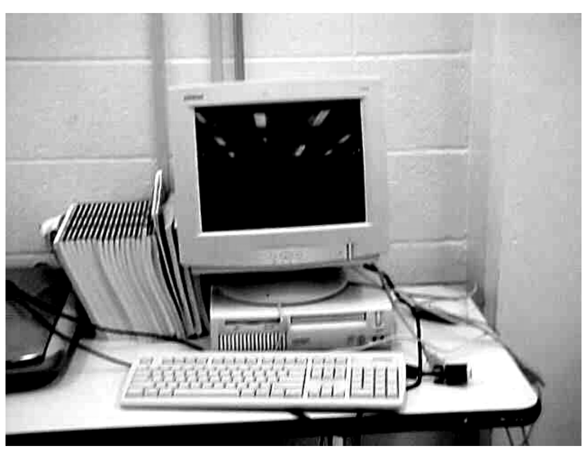
The last section of this project is the most interesting one: my students will be members of a decision-making committee considering the purchase of computers. This decision is going to be based on all the data that will have been gathered from the previous experiments. Therefore, the data must be authentic, reliable, and real, since it is going to be used for an important decision. The aspect of data integrity will be a steady issue in this section. The team will be exposed to the well-known problems of FF&P (fabrication, falsification, and plagiarism) and how these might result in erroneous decisions that might cost a company millions of dollars (Judson).

In summary, the unit of Computers and Technology will improve many of my students' academic skills of collection and evaluation of scientific data and the problems faced when there is falsifying of data to obtain personal advantages. The unit will train my students in communicating scientific information as scientists communicate in the real world. Finally, the unit will enrich my students with scientific concepts that they might not otherwise be able to develop during regular Chemistry classes. This unit proposes to address not only the TAKS requirements, but will be used to train my students in the inquiry process used for making excellent science fair projects (Widger). The quality of the high school science fair project is related to the motivation and mentorship of the students. The teachers involved in the investigation process make a monumental difference.

WASTE MANAGEMENT AND TOXIC DISPOSAL

The students are ready to apply theoretical concepts to environmental chemistry after researching the following ideas. My students will learn a new language: the language of waste management and toxic disposal (*SEPUP Module*). This topic is very important for the students since computers do not have any information related to the disposal of such an electronic apparatus or the regulations which should be followed for recycling and reusing them.

I will open the unit by motivating my students with the following real life situation: an old computer will be placed in front of the students' desks.



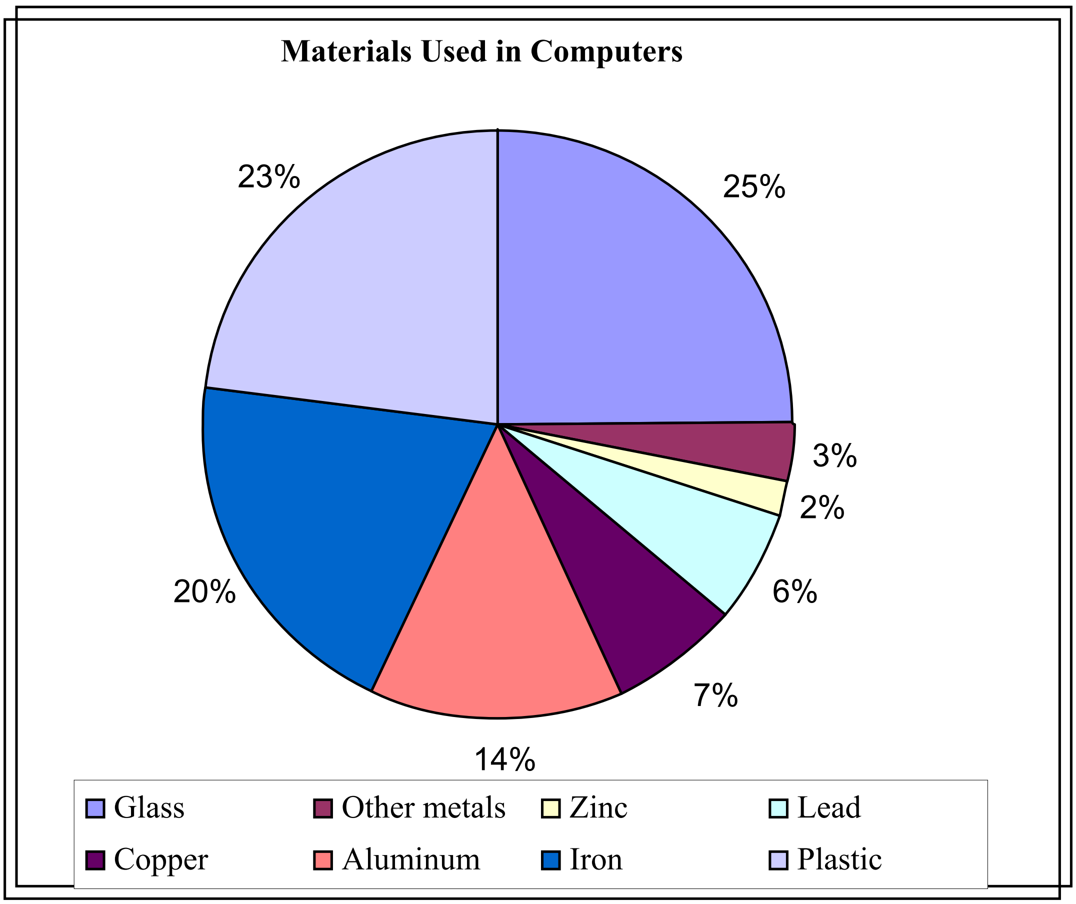
Two students are going to be selected to dramatize a situation in which an old computer is going to be thrown away. The purpose of transporting the problem to my students has the intention of determining how they get rid of the old computer either at home or any other place. I consider this exercise as the most effective way for my students to become involved with the problem of dealing with old computers and also to check their experiences with respect to this problem. Then, I will question them by using structured questions based on the Bloom taxonomy. Would you have done the same thing if you were a manager of a company? Why or why not? (Comprehension); what can be done with the old computer? (Analysis); what is inside a computer? (Knowledge); did you have to get rid of the old computer or could you have used it? (Evaluation); have you bought a new computer? (Comprehension); what happens to the old computer after it is thrown away? (Knowledge); how does a person decide when to replace an old computer? (Evaluation); what do you need to know before buying a new computer? (Knowledge) (*SEPUP Module*).

Since this unit is designed to be a practical or hands on unit, I will expose my students to a unique experience: dissembling an old computer. They are going to have screwdrivers, pliers and any other mechanical tools necessary to implement this first step.

Once this activity has been completed and all the electronic components have been set aside, the students will classify the parts according to the type of materials they are made of: plastic, glass, iron, aluminum, copper, lead, zinc, and other metals. They will then be asked to analyze the type of materials they are looking at and to draw a pie chart based on the observations being made. The new questions will be of the same nature as in the case of the dramatized act, since these questions should be correlated to Bloom's taxonomy. Do you think there is any restriction on the disposal of electronic products such as computers? Why or why not? (Synthesis); what are computers made of? (Knowledge); what parts of the computer do you think are made of glass? Metal? Plastic? (Application); why do you think this specific material was used for this part?

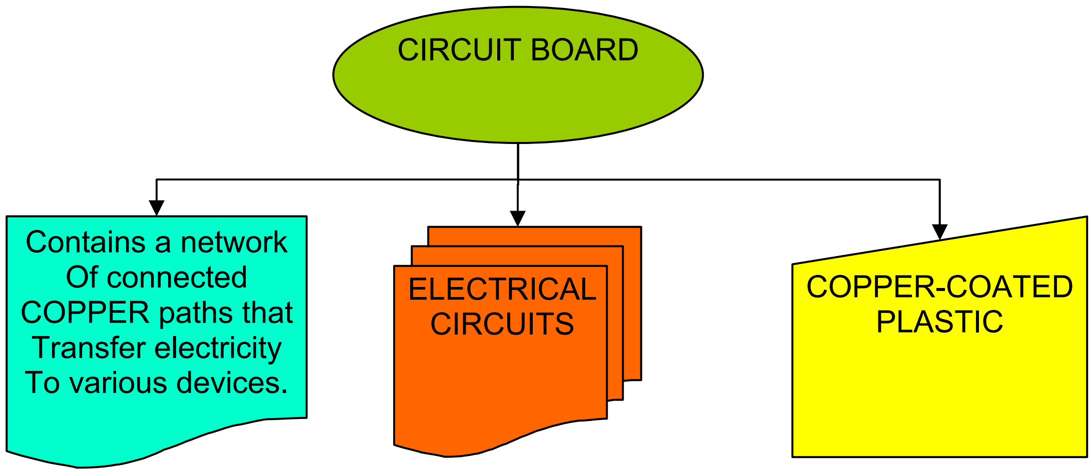
(Application); what material do you think is most abundant in a computer? (Synthesis) (*SEPUP Module*).

The following pie chart will help answer the questions my students will be exposed to. Then I will use this pie chart to train my students to translate their observations into a graph since this is the most important process a scientist needs to develop during field observation. My students will have this extraordinary opportunity to practice a Mental Scientific Exercise of graph translation by observing a computer broken apart.



The investigative team is now ready to concentrate on one aspect of the broken down computer: the circuit board. The students will review the definition and the functions of the circuit board by looking at the different circuit boards, which are found inside the computer. After they have finished the process of observation, the students will review the following diagram as a summary of the major aspects of circuit boards.

PRODUCING TOXIC WASTE



PRACTICAL WORK

Now my students are ready to begin the initial practical work for this investigation. Initially, they will be asked to fill out the Standard of Safety Regulation form required in the state of Texas. They will receive these forms prior to the investigation as their parent's or guardian's written authorization is required when working with chemicals. The school nurse is going to be involved as well. She will be informed of the safety data of the chemicals used by the students in this practical laboratory (Texas Safety Standards).

The students will receive a copy of "Creating a Computer: What Waste is Produced When a Computer is Manufactured?" (*SEPUP: Issue-Oriented Science*). The students will analyze it and design an outline of the procedure for the practical work. The practice of asking the student to design an outline of the procedure is meant to avoid students carrying out a "by the cook book recipe" style practical. The teacher will approve this outline before the students receive the chemicals and the materials for the activity. Then the students will start the practical process by designing the circuit board. The session will be concluded by completing the circuit boards all at once so etching can be done in one night.

The following session will be the most crucial one, since the finished product and the waste chemicals will be studied in detail. Initially, the students are going to compare and contrast all the circuit boards that will be produced by their group. There is an important conductivity test that will determine the most precise and accurate circuit board.

Five important questions should be addressed to the students: "What do you think should be done with the used copper (II) chloride solution?; should the water used to rinse the circuit boards be handled in the same way as the copper(II) chloride solution?; why or why not?; what type of design makes the best circuit boards? Why? Describe the changes in your circuit board and the copper (II) chloride during the etching process. What did you learn during this investigation about how computers are made?" (*SEPUP*). All of these questions will prepare my students for a brainstorming process before the chemical explanation of the etching procedure.

At this point in the investigation, the teacher is ready to introduce the analysis of the products: circuit boards. The teacher will conduct the following explanation of the chemistry interpretation of the etching process.

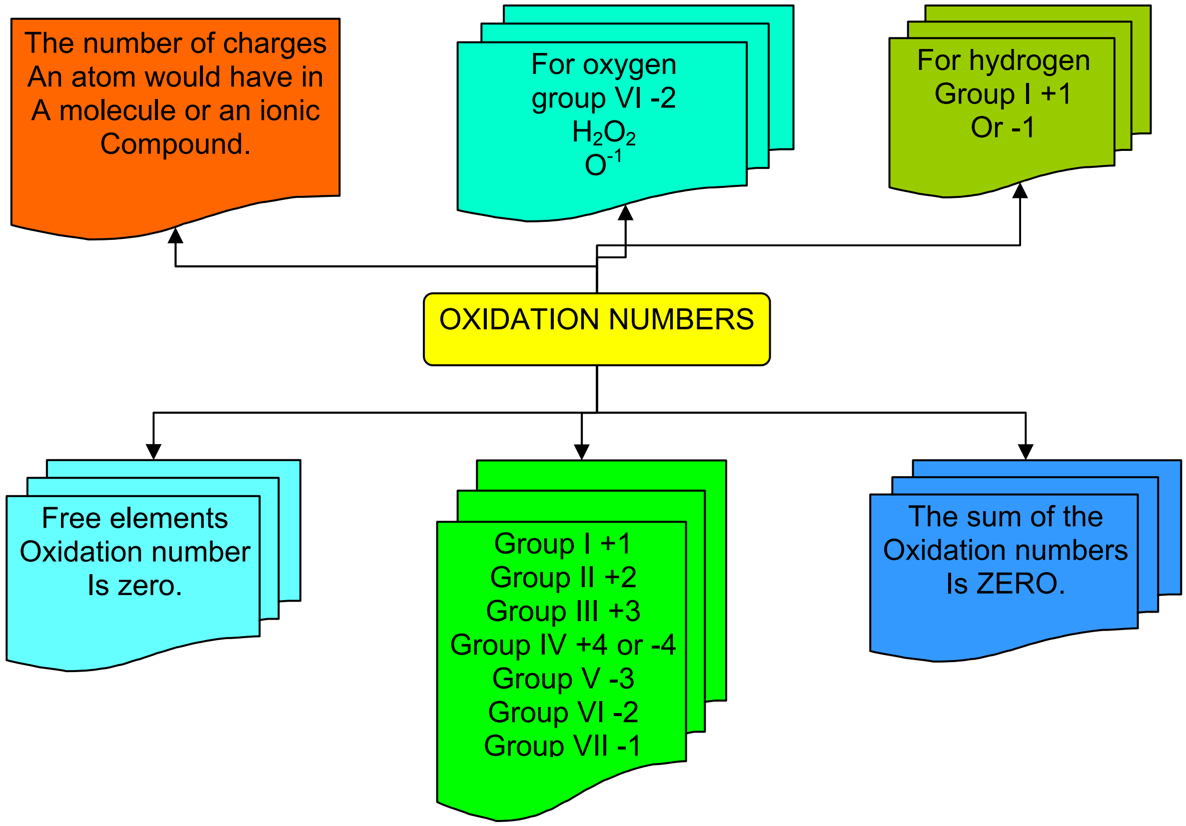
PRODUCING TOXIC WASTE

- SYNTHESIZING: discuss the waste produced during the etching process.
- What do you think happens when the copper-plated circuit board is placed in the copper chloride solution?
- $\mathbf{Cu_{(s)} + CuCl_{2(aq)} \rightarrow 2CuCl_{(s)}}$
- OXIDATION-REDUCTION REACTIONS
- Electron transfer reactions.
- Half reactions: shows the electrons involved.
- $\mathbf{Cu^0_{(s)} \rightarrow Cu^{+1} + 1e^-}$ (oxidation reaction: loss of electrons-increases in oxidation number)
- Reducing agent: donates electrons
- $\mathbf{Cu^{+2}_{(aq)} + 1e^- \rightarrow Cu^{+1}}$(reduction reaction: gain of electrons-decreases in oxidation number)
- Oxidizing agent: accept electrons.

- $\mathbf{Cu^0_{(s)} + Cu^{+2}_{(aq)} \rightarrow 2Cu^{+1}}$ NET IONIC EQUATION.

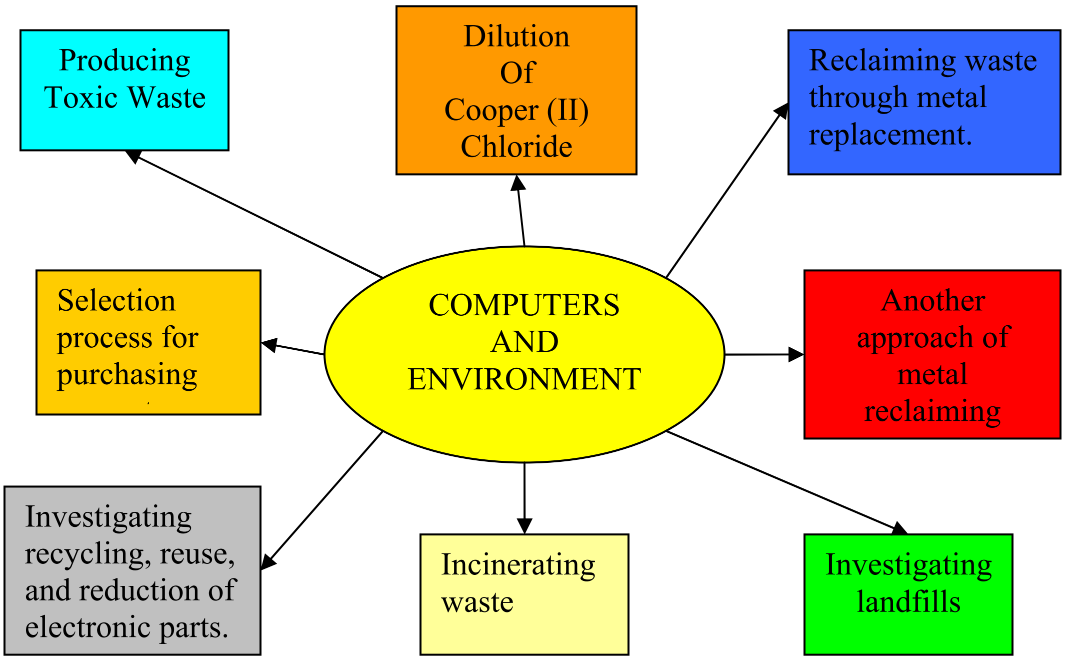
The students will now be prepared for the oxidation number theory and for the topic of redox reactions. In my experience as a chemistry teacher, the majority of the students find this topic difficult since it requires a good mathematical foundation of real numbers (math operation with positive and negative numbers). Also, the students have difficulty locating the elements in the periodic table and relating the elements with the corresponding oxidation numbers. During this practical exercise, I have reduced the pressure of memorizing the information of oxidation rules. My students will learn how to inquire, rather than how to memorize. Inquiry and observation is the key for teaching this topic with a great degree of success.

PRODUCING TOXIC WASTE



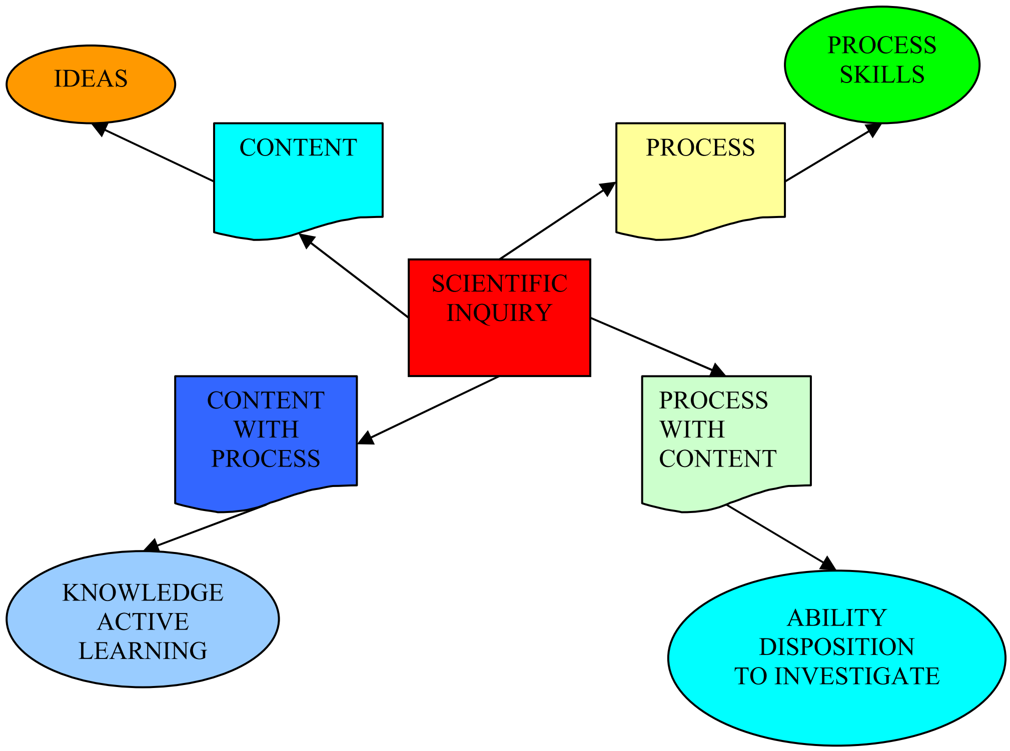
At this point in the investigation, the following project diagram illustrates the possible research activities my students could select. The students will select one topic based on its nature and the desire to learn more about the topic. The best way to proceed with this step is by placing the titles of the possible investigations in a bag and allowing the students to randomly select their topic. After the selection process, the students could trade topics with other students if they wish to do so (Widger). This minimizes the "I am stuck with this topic" problem.

PROJECT DIAGRAM



This unit is going to be taught by the application of four different perspectives of the Inquiry-Based Science Instruction Theory. Scientific inquiry will imply several aspects in this unit. The process of inquiry will represent the best illustration of such an important concept. A teaching strategy to ask questions under the Socratic Method will be another dimension of this work. Promotion of scientific investigation by experimentation and reasoning will be considered as the most precise definition of the process of scientific inquiry (Inquiry-Based Instruction).

Taking into consideration the dilemma between content and process in education, there are four aspects to be considered whenever the scientific inquiry will be applied: content, content and process, process and content, and process. The following diagram is a modified version extracted from the article Inquiry-Based Instruction written by Eugene Chiappetta (*The Science Teacher)*.



During the process of scientific inquiry, there are some steps to follow. For instance, the initial aspect of this process is recognizing the existence of a problem. The research team will state the problem as related to the disposal of old hardware. This problem is a real life problem and the students will ask real life questions. The type of questions formulated will be related to the nature of the desired research. Therefore, the teacher will play an important role as a moderator in this section of the project. The main objective at the stage of formulating the question is to raise the curiosity of the students. Once this step has been completed, the students will proceed to guess a tentative answer or a solution. A hypothesis acts as a guide for the investigation. Since different activities are going to be carried out, different hypotheses are going to be formulated and be related from one practical to another. We will go on then with practical steps or the hands on session: testing the hypothesis. During this stage, the students will manipulate materials and reagents to follow a series of procedures. The students will have the opportunity to modify the procedure in the case of discovering another way to obtain useful data. The teacher will monitor the students, checking their progress and the authenticity of their data. The teacher's role will change then to that of a proctor or the legal authority for validating the data. During the final stage of the presentation, the students will evaluate the results and conclusions. The teacher, assuming once again the role of an organizer, channels the students' ideas to a solution to the real problem.

In conclusion, this unit might help to overcome the crisis we teachers experience by filling certain holes in our present curriculum. The first aspect I consider important is that the unit proposes another approach of teaching the scientific method by inquiry.

This process can be achieved by building a camaraderie among teachers and students, which is an essential element for researching, learning, and teaching (Coles, 1993). In this context, students will take their investigations as their own which leads to achieving high levels of self-esteem, self-efficacy, and self-respect while doing the investigation. The unit will offer an opportunity for the students to carry out activities that they need to do to learn process skills and cognitive control. The students need to experience a real life situation inside the classroom since we teachers desire to prepare students better for the real world. Isn't the priority in our teaching practice to direct our attention to the process of learning and to train our students how to think and learn by themselves? As a consequence, we teachers should keep in mind the purpose of investigating current problems without specific answers by letting the students research the possible solutions to their problems. Keep in mind that the teacher should train students in how to study, research, and analyze raw data that they have collected. This will allow the students to formulate generalizations and conclusions based on their own findings. The key to this unit lies in producing an atmosphere of cooperative learning by either inductive or deductive practical sessions.

The last aspect I consider important to this unit is the improvement of the quality of science fair projects. Whenever the students are working unsupervised and unattended, their projects tend to be poor and unmotivated since they do not know how to research or discover (Widger). Scientific discovery and the method of hypothesis-driven investigation is a learned skill best taught by practical experience. If not, the most well known problems might arise: plagiarism and malpractice of science fair projects.

Finally, this unit might transform the initial reaction into this:

TAKS + TEKS+ UNIT → RESULTS + PROJECTS

LESSON PLANS

Lesson One: Producing Copper (II) Chloride Solution as a Toxic Waste

Objectives

- Identify oxidation-reduction process. (TEKS 10.A)
- Demonstrate the use of symbols, formulas, and equations in describing interactions of matter such as chemical and nuclear reactions. (TEKS 11.B)
- Compare unsaturated, saturated, and supersaturated solutions. (TEKS 13.A)

Introduction

Open the section with an explanation of oxidation numbers of elements and the periodic table. Relate the number of electrons in the outer shelf of the atoms and their position of the periodic table. Concentrate the student's attention to the element copper and its two oxidation numbers +1 and +2. Then explain the necessity of copper to release 1 or 2 electrons to achieve a noble gas configuration.

Concept Development
Ask the students to review the concept of oxidation numbers, oxidation, reduction, and redox reactions. The aspect of half ionic equation should be addressed toward the oxidation half ionic equations and reduction half ionic equation. Then show the students how to obtain a net ionic equation by adding the two half ionic equations. (Hint: OIL RIG, oxidation is loss of electrons, reduction is gain in electrons or LEO (the loin) says GER, loss of electrons is oxidation and gain of electrons is reduction)

Student Practice
The students carry out the activity of Producing Toxic Waste from the *SEPUP Module*.

Pre-Lab
Divide the class into groups of four students. Discuss safety regulations according to the Texas Safety Standards. Review the outline of the procedure of the lab activity and the set up of the activity.

Post-Lab
Each team will present the results for the rest of the class followed by a discussion of the outcome. The discussion should be oriented towards the possible solution of disposal of the copper (I) chloride solution into the environment.

Assessment
Students are going to be evaluated according to their personal skills during the practical work. The assessment process will measure the communication skills in both the written and oral presentation of the observations and results of the practical activity. A power point presentation will be required for every group and the class will democratically vote for the best one.

Closure
- Students answer multiple choice and structure questions from the chapter of Oxidation-Reduction reactions of the Chemistry book.
- Students answer questions from the TEKS Review and TAKS Preparation and Practice Manual for Redox reactions.

Resources
The textbook *Chemistry* by Anthony C. Wilbraham et al and the following Internet resources:
- <http://www.svtc.org/hightech_prod/desktop.htm>
- <www.epa.gov>

Materials and Supplies
- Safety goggles
- Piece of copper-coated plastic
- Plastic etching tray
- Plastic container with lid for Copper (I) chloride solution
- Plastic container with lid for Copper (II) chloride solution.

Lesson Two: Copper (I) and Copper (II) Ions: Identification and Concentration

Objectives

Investigate and identify properties of mixtures and pure substances. (TEKS 4.C)
Develop general rules for solubility through investigation with aqueous solutions. (TEKS 12.B)
Demonstrate safe practices during field and laboratory investigations. (TEKS 1.A)

Introduction

Initiate the activity with the tests for Copper (I) and Copper (II) ions with ammonia and sodium hydroxide solution. The students should be able to observe the difference in colors developed by each ion. Write the balanced chemical equations and the total ionic equations. Then ask the students to write the net ionic equations for the Copper (I) and Copper (II) ions.

Students performed dilution as an alternative solution for disposal of the solutions containing the copper ions. A serial of dilutions will be conducted by using the concept of part per millions (ppm) as the unit of concentration.

Concept Development

Pre-Lab

Review the main issues of safety for handling solutions contain copper ions. Go over the concepts of balanced chemical equations, total ionic equations, and net ionic equations. Describe the importance of using concept maps for reporting the results of the copper test. Review the concept of concentrations and the math operations involving the dilution process.

Lab Activity

Students will perform the laboratory activity "Dilution of Copper Chloride".

Post-Lab

Students will analyze the observation of the lab and they will share their results. Then they will discuss the following question:
"Imagine that your city is evaluating methods of handling toxic waste. Would you recommend dilution as a method of handling toxic materials containing dissolved copper? Why or why not?" (*SEPUP*)

Student Practice

The students prepare 10 solutions of Copper (I) chloride of different concentrations. They start with the highest concentration to the lowest concentration by diluting with distilled water. Then they measured the concentration of copper by forming a precipitate with ammonia solution. The intensity of the color of each precipitate is proportional to the Copper (I) ion concentration. They record the concentration in ppm and as a fraction.

Assessment
Students are going to be evaluated according to their personal skills during the practical work. The assessment process will measure the communication skills in both the written and oral presentation of the observations and results of the practical activity. A power point presentation will be required for every group and the class will democratically vote for the best one.

Closure
The students compare different concentration units like ppm, ppb, molarity, and normality. Allow time for the students to solve problems based on concentrations and ion identification. Solubility rules are going to be discovered if more solutions of different metals ions are available.

Resources
The Wilbraham textbook *Chemistry* and the *National Primary Drinking Water Regulations: Consumer Fact sheet on Copper*.

Materials and Supplies
- SEPUP tray
- 30-ml dropper bottles
- 5% ammonia solution
- Plastic container

Lesson Three: Metal Replacement Reactions

Objectives
- Make wise choices in the use and conservation of resources and the disposal or recycling of materials (TEKS 1.A) (TAKS 1).
- Organize, analyze, evaluate, make inferences, and practice trends from data (TEKS 2.C) (TAKS 1)
- Evaluate the impact of research on scientific thought, society, and the environment. (TEKS 3.C)

Introduction
The students investigate the process of metal displacement based on the activity series of metals. They will predict if a reaction will or will not occurred depending on the position of the metals in the activity series. The four metals that the students are going to investigate are: aluminum, iron, zinc, and nickel. These metals are the most used in the industry of computer manufacturing.

Concept Development

Pre-Lab
Explain to the students about the allergic reactions of Copper (I) chloride solution and advise them to report any sign of skin itching.

Go over the displacement reactions of metals and the activity series. It is wise to have a list of the activity series at hand so the students can learn the mechanism of prediction based on the series. Write balanced chemical equations and net ionic equations on the board and stress the importance of symbols of states of the reactants and products.

Post-Lab

Organize the class in three working groups, and assign each group one chemical reaction to be investigated.

For example, group 1 will carry out the investigation of $\mathbf{CuCl_{2\,(aq)} + Al_{(s)} \rightarrow}$

The following group will be in charge of $\mathbf{CuCl_{2(aq)} + Fe_{\,(s)} \rightarrow}$

And the last group will study the reaction of $\mathbf{CuCl_{2(aq)} + Zn_{\,(s)} \rightarrow}$

Assessment

Students are going to be evaluated according to their personal skills during the practical work. The assessment process will measure communication skills in both the written and oral presentation of the observations and results of the practical activity. A power point presentation will be required for every group and the class will democratically vote for the best one.

Closure

The students will graph the different level of metal disposed into waterways of different companies. Then they will compare these values with the tolerance values allowed by the EPA. (Graphing software such as Microsoft Excel could be used by the students in order to plot the graph.)

Resources

The Wilbraham textbook *Chemistry* the web pages outlining discharge limits for the following:

- Browand County, Florida <http://www.broward.org/oes/oei01000.htm>
- Fox Metro (according to Ordinance #517) <http://www.foxmetro.dst.il.us/limits/local.htm>.
- King County in Seattle, Washington. <http://www.metrokc.gov/recelec/archives/policies/put813pr.htm>.

Materials and Supplies

- SEPUP tray for serial dilutions of Copper (I) chloride.
- Dropper bottles of 5% ammonia solution
- Aluminum, iron, and zinc washers

Editors Note: Page numbers for parenthetical references were unavailable at time of publication.

ANNOTATED BIBLIOGRAPHY

Works Cited

Bloom, B. *Major Categories in the Taxonomy of Educational Objectives*. 2001. University of Washington. 1 May 2004. <http://faculty.washington.edu/krumme?guides/bloom.html>.
Lists the verbs used to write objectives according to the critical thinking process.

Chang, Raymond. *Chemistry 5th Edition*. McGraw-Hill, 1994.
A comprehensive chemistry book which students find very easy to study.

Chiappetta, Eugene L. and April D. Adams. "Inquiry-Based Instruction." *The Science Teacher* (February 2004): 46-50.
Shows the basic steps of teaching science by using the inquiry method.

Coles, R. "Point of View: When Earnest Volunteers are Sorely Tested." *Chronicle of Higher Education* (5 May 1993): A52.
Explains the most effective way to engage students in scientific research: building a camaraderie relationship between teacher and student.

Collins, James W. *Texas Safety Standards*. Texas Education Agency, 2000.
Explains all the safety precautions that you must follow in order to avoid accidents inside the laboratory.

Discharge Limits. 2002. Broward County Office of Environment Services. 1 May 2004. <http://www.broward.org/oes/oei01000.htm>.
Displays the value of the minimum level allowed by the municipal waste management in Florida.

Fox Metro Discharge Limits (Ordinance # 517). 2002. Fox Metro Water Reclamation District. 1 May 2004. <http://www.foxmetro.dst.il.us/limits/local.htm>.
Describes the process by which the District of Oregon selects a minimum level of pollutant to be disposed of in natural water by waste plants.

Houston Independent School District. *Project CLEAR Curriculum*. Houston, TX: Houston Independent School District, 2001.
A guide detailing teaching objectives and strategies.

Judson, Horace Freeland. "Patterns of Complicity." *Acumen II, No. 1*: 107.
Explains the concept of FF&P; fabrication, falsification, and plagiarism of data in scientific research.

King County Industrial Waste Local Discharge Limits (PUT 8-13 (PR)). 2001. King County Department of Natural Resources/Industrial Waste Program. 1 May 2004. < http://www.metrokc.gov/recelec/archives/policies/put813pr.htm>.
Compare the minimum values of discharge of certain water pollutants among different Districts.

Research & Education Association. *The Best Test Preparation for the TExES Examination of Educator Standards*. Piscataway, NJ: Research and Education Association, 2004.
Describes all the competencies that a certified teacher in Texas should have in order to teach inside a classroom.

SEPUP: Issue-Oriented Science. 2002. LAB-AIDS, Inc. 1 Mar. 2004. <http://www.sepuplhs.org/issue-oriented.html>.
Contains the most important information about the SEPUP modules and shows the ways to buy the modules and the training programs.

SEPUP Module Correlation to Texas Essential Knowledge and Skills Chemistry 9-12. 2004. Lab-aids Incorporated. 1 Mar. 2004. <http://www.lab-aids.com/home/catalog.asp?Id=174>.
Collections of practical activities and experiments by which the students and teachers can interact by looking for a solution to a real life problem: pollution.

Widger, William. Seminar presentations during "Exciting Experiments and the Ethics of Experimentation." Spring 2004.
Information that the seminar leader shared during our weekly, semester-long seminar sessions.

Supplemental Resources

Handy and Harman Electronic Materials Corp. *Composition of a Personal Desktop Computer*. 1996. Electronic Industry Environmental Roadmap, Microelectronics and Computer Technology Corporation. 1 Mar. 2004. <http://www.svtc.org/hightech_prod/desktop.htm>.
Shows a detailed data table about the materials used in a personal desktop computer.

U.S. Department of Health and Human Services, Agency for Toxic Substances and Disease Registry (ATSDR). *ToxFAQsTM for Copper (CAS#7440-50-8)*. Atlanta, GA: U.S. Dept. of Health and Human Services, 1999.
Indicates the permissible level of copper in natural water.

U.S. Environmental Protection Agency, Office of Ground Water and Drinking Water. *National Primary Drinking Water Regulations: Consumer Fact sheet on Copper*. Washington, D.C.: U.S. EPA, 2002.
Also available online at www.epa.gov.
Explains the point and non-point sources of water pollution.

U.S. Environmental Protection Agency, Office of Research and Development – Risk Reduction Engineering Laboratory. *EPA Environmental Research Brief: Waste Minimization Assessment for Multilayered Printed Circuit Board Manufacturing (EPA/600/M-91/021)*. Cincinnati, OH: EPA, 1991.
Also available online at www.epa.gov.
Explains the different ways to reduce water pollution by industries that produce circuit boards.