Exploring the Scientific Method:

Separation of a Complex Mixture

Developers:

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Grade Level:

4 through 6

Discipline:

General Sciences – physical properties

Goals:

Upon completion of this lesson, the student will:

1. Realize that a complex problem can be solved by applying the scientific method.
2. Understand how the scientific method may be used to solve a complex problem within a team atmosphere.
3. Recognize that scientific knowledge has been acquired through everyday activities.

Specific Objectives:

Upon completion of this lesson, the student will be able to:

- Use the scientific method to formulate strategies for separating a complex mixture.
- Identify and list critical properties that will permit the separation of a complex mixture into pure components.
- Create a working prototype that will effectively separate the complex mixture.
- Work as a "scientific team."
- Recognize each member's ability to contribute to a team effort.
- Evaluate the efficiency and creativity of each method.

Background:

Regardless of discipline, all scientists use the scientific method. The scientific method is best characterized as a logical process that scientists employ to solve complex problems. As presented here, application of the scientific method consists of five, more or less, discreet steps. When presented with a problem, the scientist first makes observations in order to try and understand the problem. Then a hypothesis for how the problem may be solved is formed. This hypothesis is then tested and refined. These testing and refining steps may be repeated several times until a final hypothesis is reached. Finally, the scientist implements his or her solution to the problem. The purpose of this lab is to teach the scientific method. In some sense, this approach is nontraditional in that we don't strive to teach a specific scientific principle, but instead a logical process. Even the student who initially proclaims that he or she "is not good at science" knows and at least partially understands many scientific principles. In this lab, the students rely on scientific knowledge that they have already acquired through life's experiences and use this knowledge to solve the problem described below.

The students work in small groups or "scientific teams." They are presented with the challenge of separating a complex mixture of everyday substances into its pure components. Initially, this challenge may seem overwhelming (and it should) but the students will soon learn how to logically breakdown a complex problem into a series of manageable steps. This lab is structured in such a way that the students will almost inevitably use the scientific method without even knowing it. The realization of "the scientific method" is attained through post lab reflective questioning. A representative questioning strategy is given at the end of the procedures section.

The materials used in this experiment are intended to be everyday household items or at the very least easily obtainable. The lists of materials presented is far from comprehensive and the instructor may easily adapt these to his or her needs and the resources available.

The instructor is encouraged to present the problem in the form of a theme. An example of such a theme is given in the procedures section; however, this may be easily adapted to reflect other current events or seasonal activities.

Materials:

The level of difficulty will be reflected by the diversity (or lack thereof) of materials used to form the complex mixture. When choosing materials, one should pay careful attention to differences in the materials' density, solubility, magnetism and size. It is recommended that materials be chosen so that it is possible to separate them by exploiting differences in the above mentioned properties.

Pure substances to be used in the complex mixture:

The mixture should be comprised of 5–10 of the following:

cork	stone
shot (B.B.)	clay
white sand	nails
sugar or salt	buttons
styrofoam	powdered gelatin
marbles	feathers
beans	spheres of any material
thread	other as appropriate

Building resources:

The following materials may be used to perform the separations and build the prototype. Any readily available materials can be used. The list given below is only representative.

pipe cleaners	comb
nylon stockings	hanger
magnets	cotton balls
paper clips	plastic wrap
cardboard	plastic knives/forks
twisties	glue
coffee filters	string
tape	boxes (any sizes)
brass fastener	nails
plastic straws	rubber bands
screens/meshes	paper plates
plastic spoons	other as appropriate

Preparation of materials:

Before beginning, a small amount of each pure substance used in the mixtures should be placed in either small vials or ziploc plastic bags. The children will be working in groups and each group should receive a mixture.

A small (1 pint – 1 quart) clear plastic container should be used to contain the mixtures which should be prepared ahead of time. Ultimately, each group would receive a "kit" containing the mixture and the allotted building resources.

Procedure:

1. Divide the class into small working groups. Each group should choose a recorder who will keep accurate records.
2. Each group receives one container of the pure substance and is given two minutes to write down as many observations about the substance as they can (an optional worksheet is provided)
3. Rotate substances from group to group at two minute intervals until each group has observed all of the pure substances.

4. Collect all of the pure substances.

5. Present the problem in the form of a scenario. Each of you has been chosen by the National Academy of Separation Scientists to isolate from this mixture the new element _____. This material is very rare, valuable and has amazing powers…. We have found tons of this mixture in another galaxy but need to come up with an efficient way of separating it. Your job is to devise a separation scheme, and build a working model or prototype for a factory that we will ultimately build for this purpose. Keep in mind that because we ultimately need to separate tons of material we can't simply use our fingers but have to build a machine.

6. Distribute the previously prepared mixtures and building resources.

7. At this point the groups are on their own to develop a separation scheme and prototype. They should be strongly encouraged to write down and draw pictures of all of their ideas and things that they try. (an optional worksheet is provided).

Reflective Questioning:

After completing their task, the students should reflect upon what they have done and how they came up with their solutions. The teacher should guide this whole class activity, with the goal being that the students will discover the scientific method. Below is a brief questioning strategy that should prove helpful in realizing this goal.

Make observations:

What did you do first?
What did you see, hear or smell?
Did you notice any similarities/differences?
What facts did you have?

Formulating Hypotheses:

What came to your mind when you were given the problem?
What "brainstorm" did you have?
How did your facts/observations help you with your problem?

Testing Hypotheses:

Did you try your ideas?

Refining Hypotheses:

Did you try things that did not work or work very well?
Did you have to change anything after trying it?
For any step did you figure out a better way of doing it?

Implementation:

After you had worked out and improved on all of your ideas or hypotheses, what did you do next?

Questions:

1. How efficient was your method/process compared to other teams' in terms of: a number of steps? b. quality of separation?

2. List the critical properties of each type of material that permitted you to separate it from the mixture.

3. How is your process/method similar to the other teams?

4. How is your process/method different from the other teams.

5. If you were required to purchase one of these methods/processes for your company, which one would you choose? Why?

6. How can you relate the critical property to your method/process?
7. What "scientific concepts" did you already know about each material?
8. How would you change this problem to make it more interesting?
9. Were you aware of the scientific method being used by yourself and others in the team?
10. What role did each team member take within your group?
11. Did anyone feel that their ideas were valuable? In what way?
12. Did anyone feel that their ideas were not valued? Why?
13. Was there a leader within your team? Why was that person considered the leader?
14. List a task or quality that each member contributed to the team.
15. Were you frustrated at any point in the experiment? If so, why? How did you handle your frustration?

Observations:

Team Name:

Sample A	Sample B	Sample C	Sample D	Sample E
Sample F	Sample G	Sample H	Sample I	Sample J

Separation Steps:

Team Name:

In _____ Out _____ _____	In _____ Out _____ _____
In _____ Out _____ _____	In _____ Out _____ _____