JOURNAL OF SCIENCE EDUCATION (REVISTA DE EDUCACIÓN EN CIENCIAS) N 1, VOL 4, pp 35-38, 2003

Teaching Science Through Research

Enseñanza de las ciencias a través de las investigaciones

Muhamad Hugerat, Saleem Zidani and Naji Kurtam

The Academic Arab College for Education in Israel – Haifa

Hachashmal St., Haifa 33145, P.O. Box 8349, Haifa, Israel 22

Abstract

The main objectives of the science curriculum are: understanding what are science, scientific methods, comprehension ability and application of science, etc. The teachers must take the responsibility of passing not only the required material but also the required skills. In order to improve the teaching and learning skills, we must utilize new strategies such as teaching and learning science through research. The experimental and research method promotes learning among students and makes the learning process more interesting. In this paper, we present four examples of teaching and learning through research in different scientific subjects.

Keywords: research methods, science, teaching and learning

Resumen

Los objetivos mas grandes del currículo de ciencias son: entendimiento de la ciencias y de los métodos científicos, la formación de las habilidades para aplicar los resultados, etc. El profesor tiene que tomar la responsabilidad no solo de exponer el material teórico, sino también formar las habilidades necesarias en los estudiantes. Para mejorar la enseñanza y aprendizaje tenemos que utilizar las nuevas estrategias organizando la educación a través de investigaciones. Los métodos experimentales investigativos no solo promueven el aprendizaje activo, sino que hacen el proceso docente mas interesante. En este trabajo se presentan cuatro ejemplos de las .actividades educativos a través de investigaciones en las diferentes asignaturas

Palabras Clave: métodos investigativos, ciencias, enseñanza-aprendizaje

1. Introduction

Knowledge of scientific subjects is very important for the pupil; it enables him to understand the natural phenomena that surround him. In order to develop the sense of research, it is necessary for the pupil in the middle and high schools to carry out scientific experiments in the laboratory. This provides him with tools to explain the natural phenomena logically and to improve his ability to think in a scientific manner (Novak, Gowin, 1984; Sanchez, Valcarcel, 1999; Van Der Valk, Broekman, 1999).

Information continuously changes. Therefore, the question that must be stressed is: "How should the pupil learn?" rather than "What should the pupil learn?" This means learning scientific principles, different thinking skills and methods of dealing with problems. The process of learning can be efficient and important for the pupil when he is a partner in the plan for it (carrying out experiments, discovering scientific phenomena and concluding general rules). The research results in psychology show that teaching scientific material without the pupils' active participation in the experiment and research makes the learning process insignificant for them. The experimental and research method promotes learning among children and makes the learning process more interesting (Cothron, Giese, Rezba, 2000; Cothron, Giese, Rezba, 2000; Kempa, 1992; Welch, Klopfer, Aikenhead, Robinson, 1981; Schwab, 1960).

The pupil is the center of the learning process. He must be active in building the experiment, executing it, formulating the questions and searching for answers in order to maintain the natural curiosity deep inside him.

The main objectives of teaching science are the following:

1. To discover and simplify natural sciences with emphasis on the use of familiar natural material from the child's surrounding.
2. To find a scientific explanation for the natural phenomena in the child's surrounding.
3. To train on the correct scientific thinking in an early age.
4. To promote the child's ability to think scientifically, to ask the appropriate questions and to formulate hypotheses.

5. To carry out experiments correctly.
6. To invoke scientific curiosity and to develop the sense of research and the ability to learn and work among children.
7. To create an opportunity for cooperation and shared work between the child and the teacher.
8. To express opinion freely, to respect the opinions of others, to draw conclusions and to present the subject appropriately.
9. To develop the child's knowledge in making scientific decisions and to describe the relationship between science and other subjects such as language and art.
10. To develop the child's knowledge of solving irregular problems through logical reasoning, to construct a conceptual mapping or a diagram, to summarize what he sees, i.e. the child must be able to organize his thoughts in a specified manner such as a table, a diagram or a summary.

2. Teaching Science Through Research. Why?

In order to improve the teaching and learning skills, we must utilize new teach strategies such as teaching through research. Why there is a strong need today to implement the idea of teaching through research? To answer this question, we must know the situation today. The teacher enters the classroom, delivers his lecture, gives the student's lots of information and sometimes he assigns homework that requires minimum thinking skills. Thus, what is the problem in this teaching method? Why there is a need for teaching by research?

The reasoning for the necessity of teaching by research is the same as that for the "failure" of the literal teaching. Out of the many reasons, the most important one is the "explosion of knowledge" that brings new challenges for educators. There is a tremendous amount of information in variety of subjects that continues to accumulate, especially in the natural sciences. It is expected that, in 2030, the amount of information in the world will double itself every week.

In these circumstances (explosion of information and obsolescence of information), the roles of the school, the teacher and the student are continuously changing.

Therefore, the traditional view that gives the school the main role in providing the student with the needed information for the future is no longer sufficient, because it is not possible to include all or even most of the needed information in future.

In order for the student to be able to handle independently the flow of information during the next millennium, he/she needs great thinking skills. Without focusing on such skills, the school graduates may not be able to handle the situation efficiently in future.

The best solution, is teaching through research. In this method, information is not presented as an "absolute fact" that must be memorized, but rather as possible answers for exciting questions. This leads to a new definition for the roles of the teacher and student: The teacher is considered as the sole source of information. The teacher's role is to find the suitable conditions for learning about different problems by the process of building up knowledge. Students, on the other hand, present their own thoughts, search the dimension of thoughts from the literature and prepare examples and explanations by themselves. Accordingly, the student's role changes: the student stops to be inactive and becomes an active learner in the process.

In teaching science through research, a problem is presented front of the students in different manners such as in writing, film, in computer or other. Under the guidance of the teacher, the students participate actively in specifying the problem, formulating hypotheses, planning experiments, analyzing and writing results. In this method of teaching, the teacher acts as a facilitator and a guide. Most importantly, the information is not offered to the students at once. It becomes clearer as they proceed with the experiment or discussion of the problem. Obviously, research does not lead the students to discover new scientific information, but it encourages them to find information that is new to them. Learning through research facilitates the scientific thinking and better understanding of the scientific process.

Learning through research constitutes an alternative for traditional textbooks and for lessons that focus on facts that lead students to think of science as a collection of unchangeable facts.

The student can use critical scientific thinking for better understanding of natural phenomena, expressions and relations between such expressions. Learning through research promotes students to ask questions, to obtain results, to analyze, to use data

and to reach the correct conclusions. Learning through research and thinking makes it possible to solve problems that face us in our daily life (Zohar, Weinberger, Tamir, 1994; Collins, Maghieri, 2000).

Therefore, the main objective of all changes and suggestion in the curriculum is making the teacher's and school's roles creative to a "small scientist" from the student. In order to make the student a scientist, he must know how do scientists work and how is science established? He also has to know the basic concepts of scientific research and possess the ability:

- To distinguish or identify the problem.
- To plan an experiment.
- To describe the results of an experiment.
- To reach conclusions from data analysis or experiment results.
- To distinguish or plan the control of an experiment.
- To separate the variables.
- To evaluate information in a critical manner.

In this report, we present calls for research based on observing a phenomenon and based on a scientific report from four fields such as: Biology, environment, chemistry and physics.

3. "Teaching Environment Through Research": Preparation of an Article: "The hole in the Ozone"

After the section of the suitable article for research, it must be divided into paragraphs; the student, then, gets the information in stages. In each paragraph, the student is faced with a group of questions relevant to the information that was provided to him. The student receives the first task numbered "Part 1". He answers orally or in writing all the questions in the paragraph. Each question deals with a different skill. It is desired that the teacher discuss the answers with his students before going on to the next part. The same is done with the rest.

Passage One

During the recent years, information is published about damage in the ozone layer in the atmosphere and about the harms to living creatures on the face of the earth as a result of that (Stern, Bouel, Turner, Fox, 1984; Manahan, 1994; Cunningham, 1994; Christidou, Koulaidis, 1996).

What is ozone and is it related to living things on earth?

Ozone is a substance that is composed of three atoms of oxygen (O_3). It is formed as a result of the effect of the ultra violet rays (UV) on the oxygen molecule (O_2). The ozone molecule is not stable and it tends to decompose according to the following formula:

$$O_3\,(g) \longrightarrow O_2\,(g) + O\,(g)$$

The ozone is concentrated in the upper layers of the atmosphere and creates there an isolated layer that absorb the UV rays due to a connection originated in the sun. The ozone, then, acts as a filter material that allows only part of the UV rays to pass through. One characteristic of each form of radiation is the length of the light wave. The shorter is the wave the more energy passes through every unit of radiation (a unit of light energy is called photon).

- According to the above information, why is the UV radiation considered dangerous? Give appropriate explanation.
- What is the central question that you would raise according to the information in the passage?

Passage Two

During the recent years a worrying phenomenon was discovered: a hole in the ozone layer was produced above the South Pole. If this hole becomes wider, it may endanger life on earth. Following this, researchers began to study the subject in order to find the reason for this hole.

According to one hypothesis, the hole in the ozone layer is the result of man's activity. The element that causes the dissolution of the ozone and the creation of the hole is chlorine (Cl) that is released to the atmosphere as a result of using the different types of spray, such as spray insecticide and cleaning chemicals. Such sprays contain thrust material that lead to the dispersal and spraying of the liquid inside the container when

someone pushes on the valve. These thrust materials contain chlorine. It is true that these materials may not cause any direct harm to humans, but they are dispersed in the atmosphere reaching its upper layers. There and under the effect of the UV rays, they are decomposed releasing chlorine items that decompose the ozone (O_3) to oxygen (O_2). Afterwards, the quantity of the ozone decreases and the hole is created.

- To your knowledge, why was the phenomenon called the "hole" in the ozone?
- In the passage, there is a hypothesis that relates man's activity with the creation of the hole in the ozone:
    a. What is the hypothesis?
    b. Suggest a measure that man can take in order to stop the widening of the ozone hole.

Passage Three

Ultra Violet radiation has a severe effect on living creatures. It is the cause of suntan following exposure to sunlight. Lengthy exposure to UV radiations may cause sunburns or even harm the genetic material that is expressed as a skin cancer.

Cancer is caused by a mutation of some kind in one cell. Following the mutation, the characteristics of the cell change; it goes through cell division without any control; it is ready at certain point to break from its tissue, move to another location in the human body and multiply itself there (metastasis). All new cells that were reproduced from the cancerous cell become cancerous. Therefore, the preventive role of the ozone layer is quite significant in protecting the living creatures on earth from the exposure to UV radiation.

- Explain why may the hole in the ozone layer cause harm for the living creatures; state the two harms.
- In the skin cells, there are pigments that absorb a portion of the UV radiations. Thus, it does not allow the radiations to enter deep inside the cells. Who is at higher risk, people with light or dark skin? Why?

4."Teaching Chemistry Through Research". Water transparency

When the subject of water transparency is taught in the first grade of the middle school, using the method of scientific thinking and learning by discovery, the following steps are taken (Johnstone, 1993; Hugerat, Basheer, 2001; Hugerat, Basheer, 2001):

First: Feeling the problem:

The teacher brings the subject of water transparency to class in the form of a question. For example: "Did it happen once that you have drank a liquid thinking it was water?" Or: "Have you heard that one of your friends had drank a liquid that looked like water, and that he was taken to the hospital?" Or: "What would happen to you if you drink a dangerous liquid that looks like water?"

Second: Statement of the problem:

The teacher raises a group of questions. The answers to such questions constitute the solution of the problem. For example:

- What is the water significance in our daily life?
- What is the chemical structure of water?
- What are the different methods you known that show that transparent water is quite different from the other transparent liquids?
- Can you state the constant relation between water and other transparent liquids?

Third: Data collection:

Under the teacher's guidance, the students carry out experiments, review literature, and watch educational movies. The following are suggestions for some experiments:

<u>Experiment One</u>:

a. Add tap water to Hoffman Apparatus (Hoffman apparatus is used to electrolyze water). Connect both negative and positive electrodes to a 9V battery. Notice the immediate appearance of air bubbles around the electrodes. Notice also that the amount of bubbles around the negative electrode is twice that around the positive one.

b. Repeat the experiment by adding cyclohexane, a transparent liquid. Notice that there is nothing happening here.

Experiment Two:

Prepare two glasses. Fill the first one with water and the second with cyclohexane. Add to each one a small amount of glycerol. Note the formation of one layer of the two liquids in the first glass, and the formation of two different layers in the second glass with cyclohexane.

Experiment Three:

Prepare thirteen glasses. Fill each one of them with an equal quantity of one of the following liquids and solutions: Distilled water, drinking soda, glycerol, ethanol, acetone, hexane, Citric Acid, Benzoic acid, pure Calcium hydroxide, vinegar, ammonia, sugar, table salt. Add to each glass few drops of red cabbage juice. Note the formation of different colors in the glasses.

Experiment Four:

1. Bring two containers; one is full of water and the second is empty. Place a live fish in one of the containers for 20 seconds only. What changes do you observe on the fish?
2. Bring two flowering plants. Add water to one of them for one week, leaving the other one without any water. Describe what happens to each plant.

Forth: Hypotheses formulation:

1. Water is significant in all different aspects of our life.
2. Water is composed from the two important elements, Oxygen and Hydrogen.
3. Water is a transparent liquid, but it is different from all other transparent liquids that may look like it.
4. There are several methods to show that the chemical behavior of the transparent liquids is different.

Fifth: Hypotheses Testing:

With the help of their teacher, the students examine their hypotheses by carrying out experiments. They reject the erroneous hypotheses. Watching educational movies and reading scientific journals may help in testing the hypotheses. Teachers may help their students to develop the skills of operating equipments, to carryout experiments in a scientific manner, and how to write chemical formulas.

Sixth: Generalization:

1. Water is significant in our daily life. Plants cannot survive without water. Plants are very essential in human life, especially in their role in photosynthesis. In addition, fish is considered an essential food for man; it cannot live outside the water.
2. Unlike other transparent liquids, water is composed of two important elements, Oxygen and Hydrogen on the rate of 2:1 Hydrogen to Oxygen (H_2O). Oxygen is essential for breathing and Hydrogen for good fuel.
3. Acidity wise, water is a balanced compound. This is unlike the other transparent liquids; they are either acidic or basic compounds in nature.
4. Unlike other transparent liquids such as Hexane, water is considered a universal solvent.
5. According to the above and bases on learning by discovery, we reached one of the most widespread rules: "Not every transparent liquid is water".

5. "Teaching Biology through Research": The dough rise phenomenon.

Research in natural science, in general and in biology, in particular, is a multistage process that begins by the phenomenon observation and asking the questions related to it; and it ends with reporting the results and conclusions (writing a scientific article, assignment, poster, etc…). Planning and execution of a scientific research require skills in scientific and critical thinking. Such skills may be learned by follow up of a phenomenon. For this purpose, we selected the dough rise. This process stimulates many questions and calls students for scientific thinking about the different stages of research.

During the activity, the students carry out an experiment and plan continuing ones, address questions, formulate hypotheses, present results and draw valid conclusions.

The opening activity is the observation of the dough rise and the identification of the effecting factors on the process.

Required supplies:

Fresh yeast, boiled yeast, sugar, flour, water, four test tubes, five teaspoons, four wood sticks, marker and a glass of hot water (30˚C), add each substance with its own spoon.

Work procedure:

a. Mark the test tubes from 1-4. The tubes are used for four different preparations of dough.
   - To tube 1, add 3 teaspoons of water, 1 teaspoon of flour, 1 teaspoon of sugar and 1 teaspoon of fresh yeast.
   - To tube 2, add 3 teaspoons of water, 1 teaspoon of flour and 1 teaspoon of fresh yeast.
   - To tube 3, add 3 teaspoons of water, 1 teaspoon of flour and 1 teaspoon of sugar.
   - To tube 1, add 3 teaspoons of water, 1 teaspoon of flour, 1 teaspoon of sugar and 1 teaspoon of fresh yeast.

b. Add the material to the tubes according to the previous instructions (Make sure not to pass a spoon from one material to another):

c. Mix the materials in each tube with a stick. Do not the stick from one tube to another.

d. Mark the height of the dough in each tube.

e. Put the tubes in the glass of hot water for 30 minutes.

Following the observation, the students hold discussions in groups according to the laid questions. The discussions summary is made in the class framework.

The subjects to be handled during the activity are: observing the phenomenon, raising questions and formulating hypotheses. In this activity, the students work with the following expressions: constant factors, changing factors, qualitative experiment, quantitative experiment and measurement units.

According to the plan, they start with the experiment by examining the factors that have an effect on the rising of the dough. The handled issues in this experiment are: Making an experiment, describing results, reaching valid conclusions based on relevant results.

The following step is processing the results. The handled issues here are: presenting results in tables, significance of sample size, importance of presentation in a unique manner to allow comparison (For this, the percent of change in the height of the dough rise is calculated), calculating the mean and presenting the results graphically.

Summary questions:

1. Comparison of the factors in the different treatments of the experiment:
    a. In what aspects are the four treatments equal?
    b. What are the differences between the treatments?
2. Yeasts are living microorganisms. Which tube has the suitable conditions for their reproduction? Explain your answer.
3. Show the different treatments including the results in the table.
4. In which tube has the size of the dough increased?
5. What is the action of the yeast in the dough?
6. What causes the dough rise, is it the yeast size or the released gas from it? Clarify your answer.
7. What treatments constituted the control in our experiment of the dough rise? Explain.
8. Give proofs showing that yeasts are living organisms.
9. To continue the research of the dough rise:
    a. Give additional questions that you wish to answer.
    b. Formulate suitable hypotheses for your questions.
    c. What experiments would you plan to examine this?

6. "Teaching Physics through Research": The Hand Battery.

In the following experiments, the human body can serve as bridge of salt (Hugerat, Aliyan, Basheer, 2001). Why? Can you suggest an experiment to prove that?

1. Connect a copper plate and aluminum plate each to one side of a micro-ammeter. Read the value obtained on the scale of the micro-ammeter. Have you noticed any change?
2. Hold one of the plates in one of your hands, leaving the other plate aside. Read the value obtained on the scale of the micro-ammeter. Have you noticed any change?
3. Hold both plates each in one hand. Read the value obtained on the scale of the micro-ammeter. Have you noticed any change?
4. In this experiment you can classify metals according to their conductivity. Attach one side of the micro-ammeter with wire connected to copper plate. Hold the copper plate in one hand, while keeping the other piece of material (Cu, Al, Fe, Zn, C, Mg, Glass, Wood, Pb, Sn, PVC, etc…) you want to test in your second hand. Connect the piece of material with the wire to the second side of the micro-ammeter and read the value obtained on the scale. Write the results in a table. According to these results, which common objects are conductors and which are insulators?
5. Connect photovoltaic solar cell via a wire to a micro-ammeter. Read the value obtained on the scale of the micro-ammeter, outside the classroom in sunny day and inside the classroom. Have you noticed any change? Explain this phenomenon!
6. Connect in series together the electric cells: the hand battery and photovoltaic solar cell, to micro-ammeter. Read the value obtained on the scale of the microammeter! Explain this result. Suggest another experiment using the same apparatus. Can you teach mathematic actions such as addition and subtraction to children using this experiment?

7. Conclusion

The research results in psychology show that teaching scientific material without the pupils' active participation in the experiment and research makes the learning process insignificant for them. In order to improve the teaching and learning

skills, we must utilize new teach strategies such as teaching through research. . In this paper, we present four examples of teaching through research, such as: The hole in the Ozone, water transparency, the dough rise phenomenon and the hand Battery.

Bibliography

Cunningham, W.P.: *Understanding our environment*. Kemp, M.J. (Ed.). McGraw-Hill companies, Inc., USA, 1994.

Christidou, V.; Koulaidis, V.: Children's models of the ozone layer and depletion, *Research in Science Education*, 1996, vol.16, no.4, 421-436.

Cothron, J. H.; Giese, R. N.; Rezba, R. J.: *Science Experiments And Projects For Students*, 3rd Edition, Kendall/Hunt Publishing Company, 2000.

Cothron, J. H.; Giese, R. N.; Rezba, R. J.: *Students And Research,* 3rd Edition, Kendall/Hunt Publishing Company, 2000.

Collins, V.C.; Maghieri, J.N.: *Teaching thinking: An agenda for the twenty-first century*. LEA, Hillsdale, New Jersey, pp.343-344, 2000.

Hugerat, M.; Basheer S.: Is Every Transparent Liquid Water, *Journal of Chemical Education*, Vol. 78, pp 1041-1043, 2001.

Hugerat, M.; Basheer, S.: Experimental Demonstration in Teaching Chemical Reactions, *Journal of Science Education*, Vol. 2, No. 2, pp 109-111, 2001.

Hugerat, M.; Aliyan, S.; Basheer S.: Simple Natural Electrical Circuits - Science and Technology Activities, *Science Education International*, Vol. 12, No. 1, pp. 20-23, 2001.

Johnstone, A.H.; in Wood, C. and Sleet, R., *Creative Problem Solving in Chemistry*, London, RSC. 1993.

Kempa, R.; *Research in Chemical education: its role and potential*. In: Mark Atley et al. (eds.), *Open chemistry*. (London: Hodder and Stougthon), pp.47, 1992.

Manahan, S.E.; *Environmental Chemistry*. Lewis Publishers, USA, 1994.

Novak, J.D.; Gowin, D.B.: *Learning how to learn* (Cambridge, MA: Cambridge University Press), 1984.

Sanchez, G.; Valcarcel, M. V.: Science teachers' view and practices in planning for teaching, *Journal of Research in Science Teaching*, 36, 493-514, 1999.

Schwab, J.J.: Enquiry, the science teacher and the educator. *The science teacher*, 6-11, 1960.

Stern, A.C.; Bouel, R.W.; Turner, D.B.; Fox, D.L.: *Fundamentals of Air Pollution*. 2nd Ed. Academic Press, INC. Orlando, 1984.

Van Der Valk, A. E.; Broekman, H. G. B.: The Lesson preparation method: a way of investigating pre-service teachers' pedagogical content knowledge, *European Journal of Teacher Education*, 22, 11-22, 1999.

Welch, W.W.; Klopfer, L.E.; Aikenhead, G.S.; Robinson, J.T.: The role of inquiry in science education: Analysis and recommendations. *Science Education*, 65, 35-50, 1981.

Zohar, A.; Weinberger, Y.; Tamir, P.: The effect of the biology critical thinking projects on the development of critical thinking. *Journal of Research in Science teaching*, 31(2), 183-196, 1994.