CONSTRUCTIVIST LEARNING: DESCRIPTION, EXPLANATION, PREDICTION IN A CHEMISTRY CLASSROOM

Yordanka Stefanova, Maria Minevska
University of Plovdiv, Bulgaria
E-mail: jorpste@yahoo.com; mminevska@yahoo.com

Abstract

Scientific description, explanation, prediction as cognitive procedures are inherent to science and deal with understanding the phenomena in the world around us. This explains the fact many studies exist on the nature of scientific description, explanation, prediction and the relationship between them.
In the majority of studies on description and explanation in teaching, the emphasis is placed on the role of the teacher as explainer of chemical phenomena and less attention is paid to student's activity in description and explanation of studied phenomena.
In this article we try to overcome such one-sidedness in addressing these cognitive procedures. We discuss the relationship between description, explanation, prediction in the study of chemical phenomena in high school, as well as the activity of teacher and student in constructing them. Taking into account the purposes of chemistry teaching, the characteristics of chemistry knowledge, the necessity of student-oriented training, the possibilities for change of learning environment, we propose a methodical model for description, explanation, prediction in the study of chemical substances and phenomena in the light of the basic ideas of constructivism.
Key words: *chemical education, description, explanation, prediction, constructivism.*

Introduction

Development of modern society poses requirements for change in education. For students finishing school be able to cope with the challenges of a dynamic world, they should possess strategies and methods for acquiring knowledge and skills. This brings up the question of mastery of cognitive methods, tools and procedures of scientific knowledge in teaching school subjects including chemistry.

Presently there are many studies in scientific literature in philosophy that explore the nature of scientific description, explanation, prediction and the relationship between them (Hempel and Oppenheim, 1948; Popper, 1959; Nikitin, 1970; Pechenkin, 1989 etc.).

In pedagogical literature on chemistry the problem of complex implementation of the interrelated activities description, explanation and prediction in the study of chemical phenomena is very scantily developed.

The majority of studies of description and explanation in training emphasize the role of the teacher as explainer of chemical phenomena. A small proportion of research in this field addresses the activities of students in description and explanation of studied phenomena (Taber and Watts 2000).

Considering the purposes of chemistry teaching, the characteristics of chemistry knowledge, the necessity of student-oriented training, the possibilities for change of learning environment, we propose a methodical model for description, explanation, prediction in the study of chemical substances and phenomena in the light of the basic ideas of constructivism, the result of its application is the understanding and inclusion of new knowledge and skills in already established structure of acquired knowledge and skills.

Discussion

From point of view of practical training in chemistry, the designing of the model is provoked by:

• The necessity of forming self-developing personalities, employing methods of scientific knowledge such as description, explanation and prediction in particular. In modern information society, globally, there is a question of changing priorities of education, bringing in foreground the development of personal qualities of students and formation of scientific literacy. Innovations in education lay emphasis on how to learn rather than on what to learn. New visions on education are associated with the need for such knowledge, skills and abilities that allow a person to cope successfully with the dynamics of life's problems and to prepare the student for a lifelong learning. This is supported by the fact that in the past decade a number of international research organizations focused on establishing the readiness of young people for life. With this reference, in late XX and early XXI century started a Programme for International Student Assessment – PISA of the Organization for Economic Cooperation and Development. The main objective of PISA is the ability of young people to use their knowledge and skills in real life, and not just the level of mastery of the curriculum. PISA focuses on the scientific literacy achieved by the students. Scientific literacy implies an ability to make scientifically sound conclusions, using scientific concepts, laws, a critical attitude towards claims of others. In connection with this, the emphasis in training should be directed to the processes contributing to the formation of scientific literacy among students, including formation of skills for independent explanation of facts and phenomena that occur in everyday life (OECD 2001, 2002).

• The majority of research on the problem of applying the description, explanation and prediction in chemistry teaching pay attention only to their use in teaching. At the same time it is emphasized that many students often do not distinguish between description and explanation (Taber and Watts, 2000).

One of the reasons, in our view, is that students do not distinguish description from explanation because the emphasis in chemistry teaching is placed on presenting the students "ready knowledge" for studied objects. The reason is that "teaching natural science rather refers to understanding the outside world than to creating a correct and scientific understanding of natural phenomena. Referring these concepts to chemistry teaching is related to the peculiarity of education and the fact that students do not always have access to the objects of the microworld and therefore they can only rationalize their perceptions of them. In this regard, Brooks and Brooks discuss the question „Why does not more thinking occur at school?". They share the idea that for long time the educational practice has been dominated by the concept that the teaching approach based on imitation is overwhelming. It is believed that if students are prepared to repeat specific parts of procedures or pieces of information, they are trained (Brooks and Brooks, 1999, p. 15).

Another reason lies in the fact that chemistry textbooks do not distinguish between descriptive and explanatory matter, they intertwine with each other.

Selection Decision

Taking into account the purposes of chemistry teaching, the characteristics of chemistry knowledge, the necessity of student-oriented training, the possibilities for change of learning environment, we propose a methodical model for description, explanation, prediction in the study of chemical substances and phenomena in the light of the basic ideas of constructivism.

Theoretical background of our research are the philosophical concepts for description, explanation, prediction and the relations between them (Hempel and Oppenheim, 1948; Popper, 1959; Nikitin, 1970; Pechenkin, 1989 etc.), as well as the basic ideas of constructivism as a main trend of research on teaching natural science for the past few decades (Spencer, 1999; Kim, 2005; Taber and Watts, 2006 ect.).

• In scientific knowledge description, explanation and prediction are treated as successive stages of scientific knowledge, which penetrate and complement each other. Description associates with the empirical level of knowledge, while the explanation and prediction with the theoretical one.

Description and explanation are closely related to each other as the accumulation of sufficient quantity of descriptive material creates the need for explanation. Explanation is not only based on description, but includes description as a subordinate element.

Prediction as a function and purpose of science relates to future objects or future observations of already existing objects. The relation of explanation to prediction lies in the concept that explanation is built with the perspective of prediction that follows it, because the main purpose of scientific knowledge is not only to describe scientific data and explain it, but based on it to derive theoretical summaries enabling prediction.

The close relationship between the three cognitive procedures, their intertwining and penetration into scientific knowledge is a prerequisite for the insufficient distinction between them in teaching, including in chemistry.

• In traditional education the teacher is the one who transmits the information, while students are passive listeners. In recent years predominates the notion of teaching based on the basic principles of constructivism.

Training based on the basic ideas of constructivism is challenging the traditional concepts of teaching and learning. In traditional learning, as emphasized by Brooks and Brooks, learning is considered as imitative activity, as process that involves students in repetition and imitation in presenting information (Brooks and Brooks, 1999, p. 9–15).

In the light of constructivist practices the personal experience of students in their interaction with the outside world is of particular importance for learning. This, in turn, helps students to learn, change and transform the new information. This experience helps learners in absorbing new information and transforming the knowledge they possess. Environmental conditions, offered by the adults, play a significant role in developing the abilities of students to set problems and solve them independently. Thus the joint activities of teachers and students in school would be geared towards students and prepare them for successful lives as adults (Brooks and Brooks, 1999, p 9 - 15). Constructivist pedagogy focuses more on the creation of knowledge rather than transmission of knowledge (Berg, 2006, p 155).

Basic concepts of constructivism on which we built the methodical model of description, explanation, prediction in the study of chemical phenomena (Brooks and Brooks, 1999; Kim, 2005; Colburn, 2007a, 2007b; Taber, 2000a, 2006b, 2006c) are:

- Knowledge is built up through the personal experience of the learner.
- Knowledge as a personal understanding of the outside world forms through learner's personal experiences rather than through the experience of others.
- New knowledge is acquired on the basis of other knowledge structures.
- Learning is an active process of development of meaning, based on personal experiences. Learning is seen as an evolving process of understanding the real world by the learner.
- In learning, knowledge is created in the context of situations close to everyday life.

In these theoretical bases we design the Methodical model for description, explanation, prediction in the study of chemical substances and phenomena.

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Methodical Model for Description, Explanation, Prediction in the Study of Chemical Substances and Phenomena

Description in the study of chemical substances and phenomena is realized in recording the test results and translating them into the sign system of chemistry science. The main structural elements of description are:

1. Discovery and definition of essential, necessary and sufficient evidence, aspects and properties of facts.
2. Discovery and definition of a common feature of facts, concepts.
3. Discovery and definition of distinctive, necessary and sufficient features, aspects of facts or concepts.

Cognitive activity of students is based on the model of active learning in and through experience and is implemented in a model that is close to the cycle of learning which is discussed by Spencer (Spencer, 1999). Students construct their own knowledge rather than receive ready information. Construction of description goes through the following stages:

First stage – Exploration. At this stage students perform specific activities such as observation of samples of studied substances, performing chemical experiments in order to collect data, analyzing texts containing information about the specific substance, solve problems independently. Work is performed in small groups of 4-5 students. The purpose of this stage is to gather empirical data on the substances.

Second stage – Concept Invention. This stage is related with processing collected information. Students arrange collected data in a manner of their choice and present it to the entire class. The goal of this stage is to analyze information and propose models for its arrangement and systematization.

Third stage – Application. This stage is associated with summarizing collected data, its arrangement and systematization, statement of hypotheses and their verification.

The developed model is suitable for implementation in studying properties of specific substances which are widely used in practice.

We present an example of implementation of the model in describing the physical properties of aluminum. This topic is appropriate for independent construction of description, because aluminum is a substance which is safe to handle and derived knowledge is interesting and meaningful to students because aluminum products have wide application in practice.

Physical properties of aluminum:

First stage: The student are given samples of aluminum: pellets, aluminum foil, aluminum wire, and the following tasks are set:

Task 1. Take aluminum samples in hand and examine them carefully. Record the visible characteristics.

Task 2. Take a long piece of aluminum wire with a pinch and heat it carefully in the flame of a spirit lamp. Determine whether it is heated also at the end, that was not in the flame of the spirit lamp.

Task 3. Try to bend a piece of aluminum wire. Can it be rolled into a spiral?

Each group is given a table providing some physical constants of the substance – melting temperature, density and others. The task is: Read carefully the given physical constants of the substance aluminum and based on them try to characterize it.

Second stage. The students in the workgroups discuss and sort collected data and then present it to the class. They discuss possible conclusions, which could be made on the basis of data collected.

Possible conclusions are:

- the observation of samples of aluminum determined that it is solid, with silvery white color, and has a metallic luster.
- taking a piece of aluminum in hand revealed that it is lightweight.
- heating the aluminum wire in the flame of a spirit lamp at one end showed that it is

also heated at the other end. This gives us grounds to conclude that aluminum is heat conductive.
- an attempt to bend aluminum wire and roll it into a spiral showed that it can be done with ease. This gives us grounds to say that it is ductile.

Third stage. At this stage students are given the task to name familiar substances which have similar properties to those of aluminum. The teacher records all responses on the board. Then the general properties of aluminum are commented and those of previously studied substances. Based on this aluminum is classified to a certain class of substances – metals. These properties are – metallic luster, silvery white color, thermal conductivity. After determining the properties of aluminum common with those of metals, we proceed with establishing its specific properties that distinguish it from other known substances.

Explanation in chemistry teaching is aimed at revealing the nature of studied chemical objects – chemical elements, substances, chemical reactions. The main structural elements of explanation are:
- determining the object of explanation;
- determining the theoretical grounds for revealing the nature of studied phenomenon;
- deducing a conclusion revealing the nature of studied object;
- proof of the authenticity of deduced conclusion.

Theoretical knowledge for concepts, laws, regularities, basic principles of chemical theories are the ground needed for performing the explanation. This is one of the features of explanation as a cognitive process inherent to theoretical knowledge.

Explanation in chemistry teaching is associated with the questions: „Why ...?“, „Why is it stated that ... ...?“, „What is the reason?“, „How to explain?“, etc.

Cognitive activity of students in the construction of an explanation of studied chemical phenomena passes through these stages – Exploration, Concept Invention, Application. In explanation they appear in a specific manner:

First stage – Exploration. At this stage students perform experiments staged by the teacher in advance and record their observations. Work is performed in small groups of 4-5 students. The goal of this stage is to gather the necessary empirical data that needs explanation.

Second stage – Concept Invention. This stage is related with processing collected information. Students arrange collected data in a manner of their choice and present it to the entire class. The goal of this stage is to analyze information and determine the object of explanation.

Third stage – Application. This stage is associated with statement of hypotheses, their verification and formulation of a conclusion, revealing the essence of explained phenomenon.

We present an example of implementation of the model in explaining the greenhouse effect phenomenon. The study of this phenomenon is suitable for constructing an independent explanation, because the explanation requires the existence of sufficient theoretical knowledge, based on which to reveal the nature of the explained object. Derived knowledge is interesting and meaningful to students, because greenhouse effect is one reason for raising the temperature on Earth.

First stage. The teacher introduces students into the subject by providing them with the following information. “*Greenhouse effect has always existed. The energy of the Sun reaches the Earth's surface and warms it up. Part of this energy in the form of heat goes back into the atmosphere around the Earth. The gases that envelop the Earth in the atmosphere retain the partially reflected heat and the Earth warms.*

It is reported that Svante Arrhenius predicted as early as 1906 that human industrial activity could adversely affect Earth's climate. This prognosis is confirmed by many laboratory experiments and observations of the atmosphere.

The advancement of science and technology, mechanization of agriculture led to the release of large amounts of greenhouse gases in the atmosphere – CO_2*,* N_2O*, methane and water vapor.* CO_2 *as heavier than air remains in the lowest parts of the atmosphere. It creates an envelope that prevents the release of heat in space.*”

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Students are set the task to perform an experiment which creates a model close to real situation. Work is performed in small groups of 4-5 students.

Experiment 1. Two glass beakers are filled with water. A thermometer is placed in each one of them. One of the beakers is covered with polyethylene foil. Electric light bulbs are placed in front of the two beakers, resembling the Sun and lighting up the beakers equally. Water temperature in both beakers is measured at given time intervals and the measurement results are recorded in a table.

Experiment 2. The experiments are repeated with ice cubes added in both beakers. Water temperature is measured again and the results are recorded in a table.

Second stage. Students present the results of performed tests. Resulting differences in water temperature in both beakers are discussed. The teacher directs students attention to the reasons for the differences in temperature rise in both beakers. Text information is discussed and the teacher points out one reason for raising the temperature on Earth. The object of explanation is determined – the greenhouse effect.

Third stage. Students hypothesize on the reason for the observed „greenhouse effect" phenomenon:

- emission of greenhouse gases into the atmosphere as a result of human activity. Students discuss the processes generating greenhouse gas emissions – the burning of different fuels, recirculation of carbon and nitrogen in nature, organic wastes and others.
- emitted greenhouse gases prevent the release of heat from the Earth into space;
- the Earth's temperature increases.

Prediction in chemistry teaching is determining the relationship between cause and effect, outlining the specific and its explanation through the general and vice versa, prediction of new facts and phenomena through bringing the specific to the general. Given the widespread assumption in scientific literature that explanation has a potential prognostic ability, we accept that construction of assumptions about the properties of chemical substances or phenomena may follow derived stages in the construction of explanations.

Conclusion

- Understanding of chemical knowledge means personal construction of complex cognitive structures involving knowledge, connections, ideas and involves personal experience of students, on one hand, and carrying out the procedures description, explanation and prediction, on the other, summarizing the facts already known and gaining new knowledge and understanding of the surrounding world.
- The methodical model of description, explanation, prediction in the learning of chemistry knowledge is based on the key constructivist concepts and on the philosophical concepts of this cognitive procedures. The emphasis is placed on the role of student, as active learning person.
  This model contributes a classroom climate, which is necessary for a meaningful learning activity. The students have opportunity to be involved in their own learning.
  Working together in chemistry classroom is important not only because this presents the student the way science, but because they learn better trough social interaction.
- This model stresses on the teacher's role as a leader who guides the students to self reach the essence of studied material and supports their efforts to understand it through self performing cognitive procedures description, explanation, prediction, creating a learning environment suitable for active learning.

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Adviced by Dobri Lazarov, University of Sofia St. Kliment Ohridski, Bulgaria

Yordanka Stefanova Ph.D, Assis. Professor, University of Plovdiv, 24, Thzar Assen Street, Plovdiv, Bulgaria.
Phone: 359 32 960 988.
E-mail: jorpste@yahoo.com
Website: http://www.uni-plovdiv.bg/

Maria Minevska Ph.D, Assoc.Professor, University of Plovdiv, 24, Thzar Assen Street, Plovdiv, Bulgaria.
E-mail: mminevska@yahoo.com
Website: http://www.uni-plovdiv.bg/