Teaching Chemical Reaction
Focus on Nature of Science

Stuti Srivastava*

Abstract

Development of students' understanding of Nature of Science (NOS) is an important aim of scientific literacy. Any science topic can be modified to enhance student understanding about science and how it works. In science classrooms, there should be explicit teaching of the aspects of NOS. In this paper, topic 'Chemical Reaction' has been modified to explicitly teach four aspects of NOS — the empirical nature of scientific knowledge, the creative and imaginative nature of scientific knowledge, the tentative nature of scientific knowledge and scientific inquiry.

Introduction

Teaching nature of science contributes to scientific literacy. The phrase *Nature of Science* typically refers to the values and assumptions inherent to scientific knowledge and the development of it (Lederman 1992). Researchers have revealed that teachers do not intentionally attempt to teach from the perspective of nature of science (Lederman 1999). Teacher's understanding of the nature of science stimulated them to rethink. It is possible to help students learn about NOS during teaching without deviating from the original subject matter. According to Lederman and Lederman (2004) any science activity can be modified to enhance student understanding about science and how it works. They restructured the topic *Mitosis* to help students learn about NOS. Chemical reaction is the core concept in chemistry textbooks and curriculum. There are several assumptions of NOS. In this paper following four assumptions of NOS have been focussed upon by teaching the topic 'Chemical Reaction'.

* *Survey Associate*, Educational Survey Division, NCERT, New Delhi, stutiau27@gmail.com

Empirical Nature of Scientific Knowledge

Scientists understand the natural world by observing the phenomena in their surroundings (Lederman et al. 2002). Scientists use their senses and instruments to gather data through observations and measurements. Observation of phenomena is possible in the following ways:

a. Empirical evidences derived from the observations of the natural world should be given to the pupils. Use illustrations and examples which are familiar to pupils and take examples from their surroundings. For example, reactions involved in burning a candle, photosynthesis, rusting, fizz in soft drinks.

b. Teacher can plan the activities or experiments that can be done in the classroom or in an unspecialised laboratory, with easily available materials. The process of chemical reaction can be observed by performing the following experiments:
   (i) Calcium Carbonate + Turmeric
   (ii) Baking Soda + Vinegar in Bottle (Balloon experiment)
   (iii) Sodium bicarbonate + Sodium Hydrogen Sulphate
   (iv) Lead nitrate + Potassium Iodide
   (v) Citric acid + Baking Soda
   (vi) Sodium Hydroxide + Hydrochloric acid
   (vii) Sodium Hydrogen Carbonate + Hydrochloric acid (Jayathirtha, 2013)

   For example, when students mix two or more chemicals (e.g., turmeric + cooking soda, vinegar + cooking soda, etc.) they get bubbles, clear solution, change in colour, etc. Teachers should ask them to carefully record their observation and identify the changes that occur when two chemicals react. Carefully planned questions by teachers can promote the learning of particular aspect of NOS (Lederman and Lederman 2004).

c. Concrete representations are important to explain the abstract concept to students. The second important point in the chemical reaction is that it involves breaking of the bond between atoms in the reactants; atoms rearrange and form new bonds to make the products. Teachers should be careful in demonstrating 'structural representations' of this science concept to help students comprehend the scientifically correct meaning. Scientifically correct representations of molecules can be shown to them in a video film or power point presentation. 2D model of atoms and molecules can have aconceptual disadvantages for students. 3D models of atoms and molecules help student teachers visualise the organisation of them (Eggen and Kauchak 2004). 3D models lead to a better understanding of the concept.

d. Students should be aware of the crucial distinction between observation and inference (Lederman and Lederman 1992). Observations are the statements about the phenomenon that are directly accessible to senses. Inference is cause behind the phenomenon that we predict based on our observation.

   (i) The teacher should first tell them to carefully observe the signs of chemical reaction. Teacher's questions should stimulate students to reason, why it happens. For instance, "how can we say that these are the signs of chemical changes?", "Why are the signs not representing a physical change or change in state of matter?" It may lead to elicit the inference that 'when you cannot get back the original substance it is a chemical change. The process of chemical reaction is irreversible'. When students answers these questions, it will allow you or them to understand how by using these observations they can make inferences. From these observations students will be able to draw inferences, such as "bubbles, effervescence, change in state of matter, precipitate, colour change, vapour, liberation of heat, temperature change and absorption. All these signs represent a chemical reaction, i.e., formation of a new substance. And the process of chemical reaction is irreversible".

   (ii) The teacher should make a connection between the observations of the students during experiments and the concept of chemical reaction given in the textbooks (Eggen and Kauchek 2004). Intuitively, the students cannot make sense that new substances are formed during chemical reactions. These signs arise due to the formation of a product, i.e., new substance.

Creative and Imaginative Nature of Scientific Knowledge

Science is not a completely lifeless and empirical activity. In the process of development of scientific knowledge, scientists also use their imaginative power and creative thinking. For example, structural representation of chemical reaction by atoms, ions and molecules is not directly observable. It is accessible only by imagination. Imagination is a key component of advances in chemistry at the research level (Bucat and Mocerino 2009).

While conducting scientific inquiries sometimes the teachers put a question mark and say "what do you think? What further can be done?" The students will then come up with their original ideas and that will make a point that inferences are a product of human imagination and creativity.

During empirical work scientists gain insights and produce their original scientific ideas. These ideas are always subject to verification through experimental testing (Siddique 2008).

Tentative Nature of Scientific Knowledge

Scientific knowledge advances in the light of new evidences. This knowledge, includes 'facts', theories, and laws which are subject to change. Old evidence is reinterpreted in the light of new theoretical advances. Thus, the laws of science are never viewed as fixed eternal truths. Even the most established and universal laws of science can be modified in the light of new observations, experiments and analysis (Lederman and Lederman 2004).

Consider the tentative nature of science while planning instructions or making instructional decisions. For example, explain the work of scientists, how they challenge the old beliefs with their new observations, the processes of science used by them (Wellington 2000). The development of different theories about atom promotes acceptance of the tentative nature of scientific knowledge. Lavoisier experiments in the discovery of oxygen and replacement of the 'phlogiston' theory can be discussed.

Scientific Inquiry

Scientific inquiry is a unique way by which scientists explain the world in a systematic way. The scientists begin with a question based on anomalous data, inconsistencies in proposed explanations, or insights from observations. After some explorations, the scientists propose a hypothesis from predictions, which may be deduced from inference. Experiments or tests are designed to test the hypothesis. Analysis of the data and results are often communicated to scientific community through publication. There is no strict order in these various steps. Through observations and experiments, empirical evidence, careful analysis and drawing inference they provide scientific explanations (Bybee 2002). This summary of conducting scientific inquiry by scientists can provide insights for teachers and the representation of inquiry in science curriculum and classroom. Teachers can teach scientific inquiry in the following ways:

(a) Scientific inquiry as an important pedagogical strategy can be understood with investigation of laboratory experiments. Students will learn with their personal experiences — this is an accepted teaching practice. For example, for understanding chemical reactions, when students mix two or more chemicals (e.g., turmeric + baking soda, vinegar + baking soda, etc.) they get bubbles or a clear solution or see a change in colour, etc. The teacher should ask them to carefully observe the signs of chemical reaction and draw inference with careful observation of these signs during different chemical reactions. With these observations the students will learn to infer signs, such as bubbles, effervescence, change in state of matter, precipitate, colour change, vapour, liberation of heat, temperature change and absorption. All these signs show that there is chemical reaction taking place.

In next session students can plan their own investigations in groups. Observations of the previous sessions' experiment may provide the insight for further investigation. During this further investigation, they will choose the question to answer. Then they will refine their questions by discussing with other group members and teachers and convince other group members about their questions for investigation. Provide them some lab materials for experiments. Students will experiment in their group to find the answers to their questions. They will communicate their results as scientists do. In this communication other group members can raise doubts or questions on their scientific inquiry.

b. The factor which keeps varying is independent variable and its effect on the certain factor is dependent variable. This is quite crucial for scientific inquiry. When students compare their ideas and give the reason why their observation is similar or different, the teacher should play the role of a guide. The teacher should tell the students that the amount of reactant (independent variable) varies, so its effect on dependent variable (amount of bubbles) may vary. If we consider the idea of a simple investigation to be done by students, the teacher should tell them that in order for such an investigation to be meaningful, they must keep certain factors (variables) the same, for example, while doing these experiments the temperature and pressure should be constant and then other factors, such as amount of reactant, can be changed. The teacher can discuss the following points — Which of the factors can you change? Which one have you kept the same? What is the effect of the change on the observation? When you kept one of the reactant constant did the other change? And it may then be explained, what you changed is independent, what variation you observe due to effect of change in independent variable is called dependent (Wellington 2000).

Conclusion

There is no explicit statement regarding these aspects in the existing general science curriculum or textbook (Lederman and Lederman

2004). The students do not learn NOS implicitly simply by doing science activities. Rather, the aspects of NOS a science teacher wants to emphasise, need to be planned and explicitly taught in the science classroom.

References

Bucat, B. and M. Mocerino. 2009. Learning at the Sub-Micro Level: Structural Representations. In Gilbert J.K. and Treagust D. (eds.) *Multiple Representations in Chemical Education. Models and Modeling in Science Education,* 4. Springer, Dordrecht.

Bybee, R.W. 2002. Scientific Inquiry, Student Learning, and the Science Curriculum. In Bybee, R.W. (Ed.) *Learning Science and the Science of Learning.* NSTA press. Arlington VA (Virginia).

Eggen, P.D. and D.P. Kauchak. 2004. *Educational Psychology: Windows on Classrooms.* Sixth Edition. Prentice Hall, pp. 67.

Jayathirtha, y. 2013. The Chemistry of Everyday Life. *Teacher Plus.* Available at <www.teacherplus.org/category/lets-experiment/>

Lederman, N.G. and J.S. Lederman. 2004. Revising Instruction to Teach Nature of Science. *The Science Teacher.* pp. 37–39.

Lederman, N.G., F. Abd-El-Khalick, R.L. Bell and R.S. Schwartz. 2002. Views of Nature of Science Questionnaire: Toward Valid and Meaningful Assessment of Learners' Conceptions of Nature of Science. *Journal of Research in Science Teaching.* Vol. 39. No. 6. pp. 497–521.

Lederman, N.G. 1999. Teachers' Understanding of the Nature of Science and Classroom Practice: Factors that Facilitate or Impede the Relationship. *Journal of Research in Science Teaching.* Vol. 36. No. 8. pp. 916–929.

——. 1992. Students' and Teachers' Conceptions of the Nature of Science: A Review of the Research. *Journal of Research in Science Teaching.* Vol. 29. No. 4. pp. 331–359.

Siddique, M.N.A. 2008. Ideas About Science Portrayed in the Existing and Proposed Science Curricula of Grades IXX in Bangladesh. *Asia-Pacific Forum on Science Learning and Teaching.* Vol. 9. No. 2. Available at <www.eduhk.hkapfslt/>

Wellington, J. 2000. *Teaching and Learning Secondary Science.* pp. 165. Routledge, London.