CHEM-RIDDLING: EFFECTIVE PEDAGOGY FOR TEACHING CHEMISTRY AT THE SENIOR SECONDARY AND UNDERGRADUATE LEVEL

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Teaching general chemistry is considered as a dull and boring activity especially in a classroom wherein students lack passion for the subject. In chemistry, there are several facts in the form of reactions, properties, preparation, uses, etc., which make it difficult for the student to grasp and assimilate the right perspective, resulting in monotony in teaching-learning. Under these circumstances, attracting the attention of the students and engaging their minds need innovative teaching methods. The author has been experimenting since last five years on teaching chemistry through riddles based on chemical principles and facts at senior secondary level. Riddling is a constructivist pedagogical tool. It reveals that learning can take place only when the learner relates the new information to his/her already existing knowledge, and perceives learning as a product of self-organisation and reorganisation of existing ideas. The author is hopeful that this method may interest chemistry teachers in schools and colleges and they may adopt it in their teaching programmes. Nine exemplar riddles that are discussed below are the part of several years of practice.

Keywords: Riddling, Constructivism

Introduction

In India, it has been felt since last few years that the craze for basic sciences is gradually declining at alarming rate due to growth of professional courses, engineering courses and other job-oriented courses. On the other hand there are less takers for chemical sciences as major subject at UG and PG levels in leading colleges and universities, which is evidenced form a declining number of secondary school students electing to study chemistry at the school leaving certificate level (senior secondary level), declining number of science students at the tertiary level selecting 'chemistry' as a major course at the B.Sc. level, a declining chemical industry in terms of gross productivity both for the domestic and export markets. This pessimistic public image of 'chemistry' has been systematically accentuated by the media and, most significantly, progressively declining government support for education and tertiary education in particular, coupled with declining financial support for scientific research, particularly by 'fundamental'/basic research.

This political apathy followed by pedagogical rigidity has resulted in poor image of chemistry in public as well as amongst learners. Today chemistry teaching is unpopular and irrelevant in the eyes of students. It does not promote higher-order cognitive skills, which leads to gaps between students' need and teachers' teaching.

We have to bear in mind that learning chemistry is learning to talk with chemistry. The specialised language of chemistry does not only include declarative and procedural concepts, critical terminologies, but also carries an ideological position with reference to certain epistemological criteria. The process of becoming a good chemist involves adapting to a scientific way of thinking and working by participating in chemistry activities, practising chemistry and overall developing a chemistry culture over time.

Chem-riddling

Most students find chemistry as most difficult subject. As a result of which students alienate themselves from the beautiful panorama of the subject and finally drop out from the subject. The riddling method is intended to give students more insight into how concepts are integrated in a sequential way so that it can help them to arrive at concrete conceptualisation needed to solve problems faced by them. Here, teacher is a facilitator encouraging students to participate in self-construction of knowledge by presenting views and critiquing those of others. When a teacher asks students for riddle formation, this means she/he encourage students to present and discuss alternative analysis of concepts and alternative ways of solving tasks, rather than checking if they have the 'correct' solution. Ultimately this makes students feel confident and it facilitates students' natural urge for scientific inquiry and explorations, i.e., self-paced learning. Also, this enables the teacher to establish good scientific knowledge-construction practice in classroom.

Riddling: A Constructivist Paradigm

Constructivism is derived from latin word *construere* which means to arrange or to give structure. It is a learning theory that reveals construction of new ideas, knowledge by connecting the prior experience and understanding by herself/himself. National Curriculum Framework (NCF)–2005 strongly advocates this as a way of teaching-learning. It states, child-centred pedagogy should be followed, giving primacy to children's experiences, their voices and their active participation; and knowledge will be the outcome of the child's own activity. In science education constructivists believe the students are active learners who come to science lessons already holding ideas about natural phenomena, which they use to make sense of everyday experiences, ideas about life process which they experience in course of their daily life, etc. The process of riddle making provides a vibrant platform for the learner to self-construct conceptual understanding in a vivid manner. Riddling can be done by engaging students in intense conceptual discussion and open questions aimed at eliciting justifications. The teacher may challenge students' ideas, pointing out limitations and inconsistencies. These two roles plead for an active teacher

engaging as a 'partner' to student groups running their own debates.

Example 1

I am a light, highly reactive gas.

I'm used as automobile gas.

I produce water vapour as exhaust gas.

I am the fuel of Millions' first choice. Who am I ?

Explanation: Hydrogen gas (H_2) is considered as the future fuel. I do not produce any pollution as automobile run by hydrogen gas only produces water vapour i.e.
$2H_2(g)+O_2(g) \rightarrow 2H_2O(l)+572kJ$ $(286kJ/mol)$.
It is an exothermic reaction, Hydrogen gas is highly inflammable and burn in air at a very wide range of concentrations between 4 to 75 per cent by volume.

Example 2

I am very abundant in nature and found in every organic matter.

You can see me in many forms like graphite, diamond and fullerene.

It is possible through the property of catenation. Who am I?

Explanation: Carbon. Through this teacher can cover concepts like: abundance of carbon, allotrope, allotropic forms of carbon, catenation, composition of organic matter, etc. Carbon is the 15th most abundant element in the Earth's crust, and the fourth most abundant element in the universe by mass after hydrogen, helium, and oxygen. It is present in all known life forms, and in the human body carbon is the second most abundant element by mass (about 18.5 per cent) after oxygen. The abundance, together with the unique diversity of organic compounds and their unusual polymer-forming ability at the temperatures commonly encountered on Earth, make this element the chemical basis of all known life. Different allotropic forms are: (a) Diamond, (b) Graphite, (c) Lonsdaleite, (d) C_6 (Buckminsterfullerene or buckyball), (e) C_{540}, (f) C_{70}, (g) Amorphous carbon, and (h) single-walled carbon nanotube or buckytube, etc.

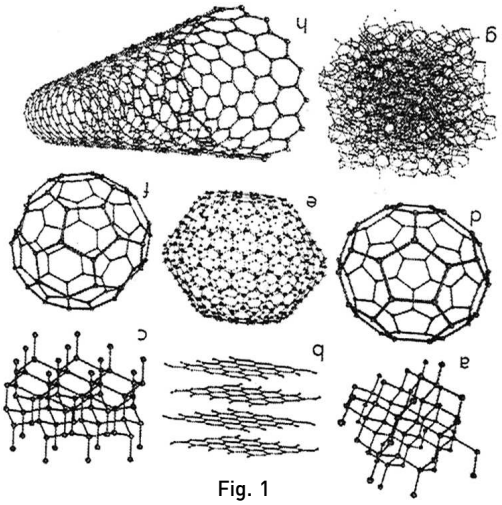

Fig. 1

Example 3

I am liquid in and colourless.

Less viscous, lighter than water.

People use me as I am cheaper than petrol.

Also used for storing sodium metal. Who am I?

Explanation: Kerosene. Concepts covered are viscosity, density, fossil fuel, use of Kerosene as common fuel, combustion reaction/oxidation reaction, etc., viz., Kerosene, a thin, clear liquid formed from hydrocarbons, with a density of 0.78–0.81 g/cm^3, is obtained from the fractional distillation of petroleum between 15°C and 275°C resulting in a mixture of carbon chains that

typically contain between 6 and 16 carbon atoms per molecule. Major constituents of Kerosene include n-dodecane, alkl benzenes, and naphthalene and its derivatives. Combustion of Kerosene is an exothermic reaction.

$$C_{12}H_{26}(l)+{}^{37}\!/_{2}\,O_2(g)\rightarrow 12CO_2(g)+13H_2O(g);\ \Delta H^{\circ}=-7513kJ$$

Example 4

In global warming phenomenon I am in 1:2:2 composition.

It comprises two different halogens and carbon.

With UV rays I undergo chemical disintegration. Who am I? (chlorofluoro carbon)

Explanation: CF_2Cl_2 (Freon-12/Du Point) Concepts covered: Global warming, green house gases, UV ray, decomposition reaction, Montreal protocol, ozone layer depletion, uses of CFCs, etc. A chlorofluorocarbon (CFC) is an organic compound that contains only carbon, chlorine, hydrogen and fluorine, produced as a volatile derivative of methane and ethane. It is also called as Ozone Depleting Substance (ODS) and it depletes ozone layer and causes skin cancer due to direct penetration of UV rays. it also causes environmental pollution. The most important reaction of the CFCs is the photo-induced scission of a C-Cl bond:

$$CCl_3F-CCl_2F+Cl$$

The chlorine atom, written often as (Cl) behaves very differently from the chlorine molecule(Cl_2). The radical Cl is long-lived in the upper atmosphere, where it catalyzes the conversion of ozone into O_2. Here ozone decomposes to oxygen. Montreal protocol restricted the use of ODS and safe use of alternate to CFCs which are conventionally used for refrigeration and aerosol.

Example 5

I am the lightest part of an atom.

I was discovered by J.J. Thomson.

I am in outer part of an atom and initiate many chemical reactions. Who am I?

Explanation: Electron. Concepts covered: Sub-atomic particle, chemical reaction initiation, orbital concepts of atom, J. J. Thomsons discovery. The electron (symbol: e^-) is subatomic particle discovered in 1897 by J.J. Thomson and his team of British physicists. It is produced in the process of photon collision. i.e $\gamma+\gamma\leftrightarrow e^{+}+e^{-}$. In quantum mechanics, the behaviour of an electron in an atom is described by an orbital, which is a probability distribution rather than an orbit. In the Fig. 2 the shading indicates the relative probability to "find" the electron.

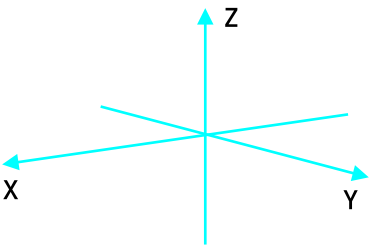

Fig. 2 : Orbitals $(\ell=0, m_\ell=0)$

Source: www.wikipedia.org/orbital

Example 6

Electric and magnetic fields oscillate me.
I am a wave and can travel anywhere.

Also my partner (radio wave) is group 2b Carcinogen.

I can make Radio, Telephone, TV, mobile live. Who am I?

Explanation: Electromagnetic radiation
Electromagnetic radiation, Radio communication, Telephone communication, Dual character (Wave and Particle nature). Electromagnetic radiation (EM radiation or EMR) is a form of energy emitted and absorbed by charged particles, which exhibit wave-like behaviour as they travel through space. EMR has both electric and magnetic field components, which stand in a fixed ratio of intensity to each other, and which oscillate in phases perpendicular to each other and perpendicular to the direction of energy and wave propagation. Louis de Broglie in 1924 that the scientific community realised that electrons also exhibited wave-particle duality so much so EMR also exhibit same duality.

Example 7

In modern industry, I am used as green solvent.

I have unique property of diffusion like gas through solids, can dissolve organic substances/ catalyst.

Being a fluid, I am used for chemical separation due to low toxicity and noninflammability.

I have no surface tension and has low viscosity.

Identify me (supercritical CO_2 fluid).

Example 8

People call me as universal solvent and polar solvents.

When heated at 374° C and 218 atm I can initiate synthetic reactions.

Under these conditions, I am categorised as cheap, clean and green solvents.

Who am I? (Super critical water)

Example 9

In the manufacturing of gold nano particles, I am used as a reaction starter.

I am highly toxic and burst into flames at room temperature.

Green chemists replace me with $NaBH_4$

This is how green chemists apply the principle of safer chemistry for accident prevention, i.e, to minimise the potential for chemical accidents including explosions and fire. Guess me!

Explanation: (Diborane B_2H_6)

Role of Teacher

According to Swami Vivekananda "True teacher is one who can throw his whole force into the tendency of the taught. Without real sympathy we can never teach well". Thus, in the process of riddling, the role of teacher is to organise information around conceptual clusters of problems, questions and different situations in order to engage the students interest. Primarily conceptual ideas are presented as broad concepts and then they are broken down into simplest forms. The learner reconstructs ideas into logical forms and finally derived conclusion, i.e., fixes the answer of it by herself/himself. Hence, the basic role of teacher is to engage students in an interactive way for the evolution of new ideas.

Conclusion

Teaching chemistry in schools and colleges aims at fulfillment of the goals of education, which covers a wide range of intended targets, i.e, the intellectual, personal and subject-society interface. Conceptual learning in chemistry needs to be approached in a relevant manner, but the teaching must also not lose sight of the fact that the attitudes, communication abilities and personal attributes amongst students (such as creativity, initiative, self-paced learning) need to be developed. This strongly calls for a paradigm shift in teaching-learning approach in chemistry. Chem-riddling is found to be an effective pedagogy for teaching chemistry at higher secondary and under-graduate level. It will not only encourage students' involvement, but will also result in a teaching approach that builds on prior constructs held by students, thus enhancing the relevance of chemistry in the eyes of students.

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