SOME ASPECTS OF THE USE OF ICT IN CHEMISTRY TEACHING

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Information and Communication Technologies (ICT) have become one of the fundamental building blocks of modern society. Many countries now regard the mastering of the basic skills and concepts of ICT as an inevitable part of the core of education. To this end, various new models of education are evolving in response to the new opportunities that are becoming available by integrating ICT and in particular web-based technologies, into the teaching and learning environment more particularly in Chemistry teaching as many students have difficulty in learning abstract and complex lessons of chemistry. This paper investigates how students can develop their understandings of abstract and complex lessons in chemistry with the aid of visualising tools: Animation, Simulation, Video, Films, Images, etc., that allow them to build clear concepts. These tools enable learning by doing and provide opportunity to explore the abstract and complex lessons of chemistry. They also enable to present information in a more dynamic, compelling and interactive way with engaging environment. The effective integration of such applications however, depends to a large extent on teacher's familiarity and ability with the IT learning environment. Keeping this in mind, in this paper various aspects of ICT for chemistry teaching are discussed and listed in the form of Compulsory Reading material. Useful links on the Websites for chemistry teaching, Learning Activity by using ICT in chemistry and resource material are given outlining thus a programme of objectives and related activities for an ICT-enhanced learning environment in chemistry teaching and learning.

"It is through formal and/or informal education that an individual can be equipped with the knowledge, skills and attitude needed to be a successful citizen, which helps him or her to adapt to the ever changing political, social and economic environment"– (UNESCO, 2003).

Introduction

Let us start this topic with an example— a senior secondary level student in China got information from the Internet that the research which won the 2005 Nobel Prize in Chemistry revealed the mechanism and process of olefin metathesis. At this point, this student was learning about olefins. He asked his chemistry teacher two questions on this information—firstly, the olefins we learned could make addition reaction and substitution reaction. But metathesis reaction was not mentioned in the book. What's more, the types of organic reaction did not include metathesis reaction; secondly, it was said on the Internet that 2005 Nobel Prize in Chemistry realised "the return of chemistry."

How to understand it?

This example illustrates that information technology has created a vivid and trans-time-and-space digital learning environment for students. It is quietly affecting the way students study. Our teachers must not turn a blind eye to it. Instead, they should use a clear mind to face the arrival of this change and consciously and actively play a positive role in use of information technology to achieve teaching objectives.

Significance of information technology in changing chemistry learning style

(Retrieved from http://Proceedings.InformingScience.org/InSITE2014/InSITE14p121- 127Huang0602.pdf)

Understanding the Problems in Teaching Chemistry

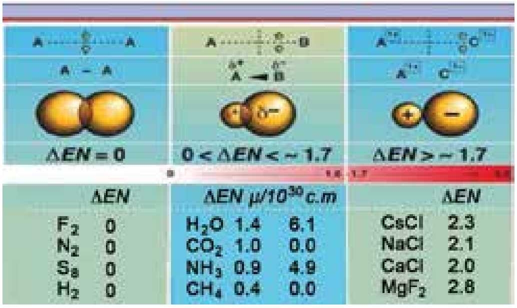
Many chemistry concepts and phenomena are abstract and complex, which can be understood and communicated only through the use of chemical representations. Along with this, understanding of chemical processes and phenomena, such as, dissolving substances, transfer of electrons, conduction of ion, inter molecular and intra molecular bonding as well as the dynamic nature of phenomena is fundamental to learning the chemistry. But the students have difficulties to understand this chemist's conceptual representation of the microscopic particles. On the other hand, when misconceptions or alternative misconception occur they hinder further chemistry learning. It is also important to identify factors affecting students understanding of the abstract and complex concepts of chemistry in their effort to construct their own meaning. This is the key to quality chemistry learning. This suggests that teachers should have to prepare an appropriate, clear and an interesting learning environment engaging their students in the participatory learning process that increases their positive attitude towards chemistry learning.

Introducing ICT in Teaching Chemistry

This can be achieved by introducing some very basic tools made available to us by technological innovations. We can understand it with an example. A teacher has taught the states of matter in the previous classes and now it is time to teach (as per the Chemistry curriculum) the structures of simple organic molecules like methane, ethane, propane, etc. The usual way is to present the nomenclature and their structures on the chalk board (which is a two dimensional object—2D). It is, however, learnt through chemistry education research that most students could not understand the three dimensional (3D) nature of the structure of the molecules. Furthermore, it is time consuming for the Chemistry teacher to draw the structures every time he or she wants to teach or review the structures for different sections of a grade level. The teacher wants to know to what extent the students understood the content taught to them on the states of matter. One way is to prepare a PPT involving pictures of actual objects and ask them to write down their responses on a sheet of paper when each slide is shown to the whole class. Note that such an approach can accommodate a large number of students in one class as long as the PPT is visible to every student.

In addition the teacher can use transparencies prepared by others. One example is the UNESCO & IUPAC chemistry teaching material entitled DIDAC. See the following examples extracted from that material. These slides can be copied or printed onto overhead transparencies and used for teaching in the Chemistry classroom.

Example 1: The link between the differences in electronegativity and the type of bonding



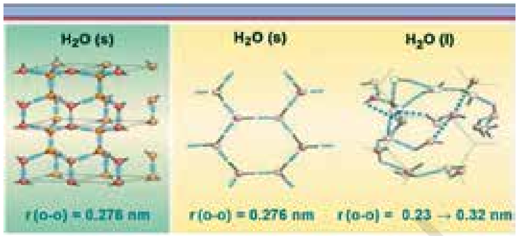
AJCE, 2014, 4(3), Special Issue (Part II) ISSN 2227-583511)

Substances built up of molecules which have clear polar bonds, e.g., H_2O, NH_3, CO_2, CH_4 do not necessarily behave as polar substances.

- It is possible that the various polar bonds in a molecule cancel each other out, or "neutralise" each other.
- The direction and charge of the dipole moments generated by the polar bonds has to be taken into consideration, as does the resulting dipole moment for the whole molecule.

CO_2, for example, is an apolar molecule with two polar bonds between the C and O atoms, each having opposite dipole moments. H_2O and NH_3 are polar molecules, CH_4 is apolar. Nonetheless, all of these compounds contain polar chemical bonds.

Example 2: Structure of water as an example of hydrogen bonding



On the left side, the three-dimensional representation of the structure of ice: the lattice contains a hexagonal structure. Each water molecule has four neighbours in a tetrahedral configuration. A very open structure that has a very low density. When it is warmed (to 4°C) the hydrogen bonds are partially broken resulting in a denser structure. On further warming the thermal agitation of the water molecules increases and the density again decreases. The right side compares the structure of ice with the structure of water at a given instant in time (computer simulation): (AJCE, 2014, 4(3), Special Issue (Part II) ISSN 2227-5835-12)

The hexagonal pattern of ice is shown by a light green dotted line. The blue dotted line represents the hydrogen bonds. The shorter the distance between the dots the shorter the hydrogen bond. The colour of the oxygen atom indicates to what extent it is out of the plane: white atoms are in the plane whilst dark brown atoms are between 0.7 and 1.0 nm in front of the plane. The light pink and red atoms are at an intermediate distance; the darker the colour the further the atom is in front of the plane. Hydrogen bonds are essential for the spatial configuration of biologically important molecules, such as, proteins.

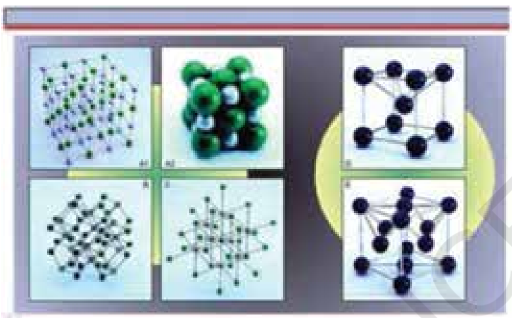
Example 3: Lattice Structures Ionic Lattices

A1 = NaCl (open structure),

A2 = NaCl (close-packed structure),

B = CaF_2,

C = $CsCl_2$

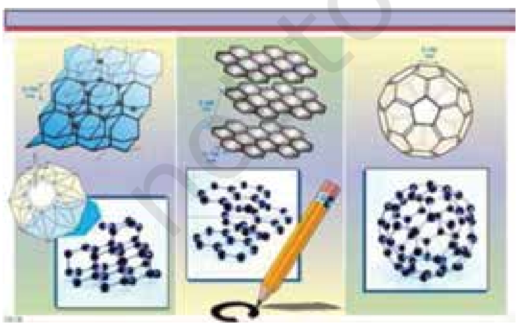


(AJCE, 2014, 4(3), Special Issue (Part II) ISSN 2227-5835-13) Metal Lattices

D = Fe (bcc unit cell)

E = Cu (fcc unit cell)

Example 4: Allotropes of Carbon: Diamond, Graphite and Fullerenes



Diamond (left)

Each atom is bonded via sp^3-hybrid orbital to four atoms in a tetrahedron. All four valence electrons are paired in bonding orbitals. Diamond is stable, being an insulator with a high melting point and the hardest substance on earth. It is transparent and has a high refractive index.

Graphite (middle)

Each atom is bonded to another three atoms by sp2-hybrid orbitals and consists of layers of flat, hexagonal rings of carbon atoms. The layers are held together by London force. They slide easily over each other. Graphite is a soft, black material and is used as a lubricant. Each atom contributes three valence electrons to the three s-bonds. The fourth electron forms a π-bond with a neighbouring atom. This is not a localised bond but it moves freely throughout the π-system. The electrical conductivity parallel to the layers is high, but is low perpendicular to the layers. (AJCE, 2014, 4(3), Special Issue (Part II) ISSN 2227-5835-14)

Fullerene, C60 (right)

This molecule consists of 60 carbon atoms divided into 20 six-rings and 12 five rings, like a football.

(In 1996 Robert F. Curl, Sir Harold W. Kwoto and Richard E. Smalley received the Nobel Prize in chemistry for this discovery.) (AJCE, 2014, 4(3), Special Issue (Part II) ISSN 2227-5835-15)

Animations and Simulations for Teaching and Learning Chemistry

Animated visualisations that show both structures and processes help teachers convey important scientific concepts in chemistry. Designers of these animations benefit from knowing how students perceive and comprehend such visualisations. Specifically, instructional developers seek to design visualisations that allow students to learn critical concepts and relationships between these concepts. For example students learn molecular chemistry concepts and relations by attending to, seeing, and understanding all the associated elements and the ways that they change and evolve during the process. Because often animations are too complex to be quickly understood, learners need to establish accurate mental models to assist in their comprehensions.

One example can be described when students watch an animation of moving molecules. The molecules are symbolised by tumbling balls of different colours coming apart and coming together. Students see these balls as pushing others so they will join or adhere. Studies have suggested that students who receive instruction including computer animations of chemical processes at the molecular level are better able to answer conceptual questions about particulate phenomena.

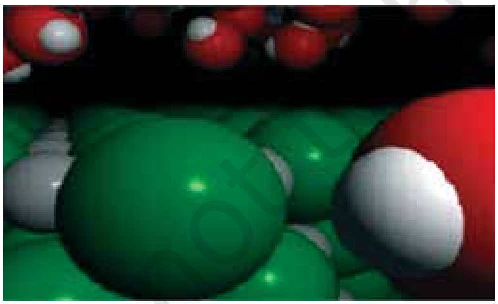


Fig. 1: Molecules from Salt Dissolving in Water Animation

(Ref.: Tasker, Dalton, Sleet, Bucat, Chia, and Corrigan, 2002).

Besides animations help students better understand dynamic molecular processes. Animations and simulations visually help students understand difficult concepts related to the dynamics of complex chemical systems including molecules and reactions. Students' mental models are positively and negatively affected by viewing animations of basic chemical processes. Combining animations with microcomputer based laboratory experiments support student integration of multiple representations of chemistry concepts. Many lab experiments are complemented by multimedia simulations and animations that represent the phenomenon being explored by students. Often, instructors help students use animations and technology to stay on task and to solve a complex scientific problem where guidance is provided as needed to sustain educational progress among the learners. Laboratory instruction helps students understand the connections between their macroscopic observations of chemical phenomena and the underlying molecular processes. Visual representations help students develop multiple representations for the same chemical phenomenon during laboratory work. Molecular animations are an external representation that corresponds to the mental images that chemists use to solve authentic research problems.

Teachers' Formation and role in ICT integration in Chemistry

Chemistry teachers can infuse ICT in all aspects of professional life to improve student learning and the management of learning processes. ICT enables teachers to become active and creative in stimulating and managing the learning process, by infusing a range of preferred learning styles and uses of ICT in achieving educational goals. Chemistry teachers can master authoring tools, animation tools and multimedia tools to develop instructional software in Chemistry in accordance with the ICT-enhanced teacher standards. For instance, a Chemistry teacher can start designing their own lessons by using free software available for educational purposes. One such software is the Advanced Chemistry Development (ACD/ChemSketch). ACD/ChemSketch is a chemical drawing software package from ACD/Labs designed to be used alone or integrated with other applications. ChemSketch is used to draw chemical structures, reactions, and schematic diagrams. It can also be used to design chemistry-related reports and presentations. ACD/ChemSketch has the following major capabilities: **Structure mode** for drawing chemical structures and calculating their properties, **Draw mode** for text and graphics processing, and **Molecular Properties** calculations for automatic estimation of Formula weight, Percentage composition, Molar refractivity, Molar volume, Parachor, Index of refraction, Surface tension, Density, Dielectric constant, Polarisability, Monoisotopic, nominal, and average mass.

ACD/ChemSketch can stand alone as a drawing package or act as the "front end" to other ACD/Labs software such as the NMR Predictor engines. Once ACD is installed in the computer. (TK), the Chemistry teacher can follow the instructions or user manual for drawing and animating (PK), for instance, the structures of organic molecules (CK). (AJCE, 2014, 4(3), Special Issue (Part II) ISSN 2227-5835-18)

The animated structures with different models such as, wire frame, sticks, ball and sticks, space filling, dots only, and discs can be used to challenge students' misconceptions about the structures of the molecules through the teacher's application of this particular activity.

Students' Participation in the use of ICT in Chemistry

ICT becomes an integral part of daily personal productivity and professional practice. The focus of the Chemistry curriculum should be now much more learner-centered and should integrate the subject in real-world applications, both in real and virtual environments. For example, students may work with community leaders to solve local problems related to water by accessing, analysing, reporting, and presenting information with ICT tools. Learners' access to technology is broad and unrestricted. They take even more responsibility for their own learning and assessment. ICT is taught as a subject area at an applied level and is incorporated into all vocational areas. The institution has become a centre of learning for the community. (AJCE, 2014, 4(3), Special Issue (Part II) ISSN 2227-5835-19)

Teachers need to master special software, learning management system, simulation and modelling tools, networking and various Web tools, in order to innovatively transform the teaching and learning system. At this stage, the teacher is a creative and innovative person. They can design, implement and evaluate a range of technological tools in teaching Chemistry and across the curriculum. At this stage the teacher should be able to design Chemistry Website at least using open source software like Joomla. They should also be able to use the content management software like Moodle for wider and online learning.

Some Aspects of the use of ICT in Chemistry Teaching

We will now discuss some aspects of ICT use in Chemistry in form of Compulsory Reading, Useful Links, Learning Activities, Project Based Learning, etc.

Compulsory Readings

1. UNESCO (2002). *Information and Communication Technology in Education: A Curriculum for Schools and Programme of Teacher Development (2002).*

The chemistry student, teacher or instructor can use the manual for developing subject-specific approaches to the use of ICT as a tool for designing new IT learning environments and helping their future students to use ICT. Many teachers are keen to develop professional expertise on ICT use in education. This book is designed to raise the knowledge for ICT applicability to subject-matter content in science, mathematics, languages to a minimum level, and to provide a foundation for further professional development.

2. Tuvin-Arad I; and Gorsky P. (2007). New Visualisation Tools for Learning Molecular Symmetry–a Preliminary Evaluation Department of Natural Sciences, The Open University of Israel, Israel. Published online: *Journal of Chemistry Education Research and Practice*, 2007, 8 (1) 61–72

This research article is about molecular visualisation in chemistry learning using new IT visualisation tools. It describes how a Website that helps students visualise and locate symmetry elements on three-dimensional (3D) molecular structure was developed. The article includes textual explanations and a tool kit -an open tool-that enables students to draw symmetry elements for any molecule in 3D. The paper focuses on how students learned while using the symmetry tool. The study provides empirical support for the use of visualisation tools in molecular symmetry and other areas of chemistry such as inorganic spectroscopy, quantum chemistry grounded in visualisation.

3. Burewicz A. and Miranowicz, N. (2006). Effectiveness of Multimedia Laboratory Instruction. Department of Chemistry Education, Faculty of Chemistry, Adam Mickiewicz University Poland. Published. *Journal of Chemical Education Research and Practice* 2006, 7, (1) 1–12

The article outlines the process of ICT integration in traditional chemistry laboratory teaching. It describes the development of a computer based programme for testing the effectiveness of using interactive laboratory instructions in chemistry teaching. Overall the study shows that the use of interactive laboratory instruction increases performance in the resulting laboratory skills and shortens time spent on completing laboratory exercises and tasks. A number of transition steps were found to characterise the integration of ICT-laboratory learning environments.

4. Kennedy, D. and Finn, Sean. (2000) The Use of Data logging in Teaching Physics and Chemistry in Second-level Schools in Ireland: A Report submitted to the National Centre for Technology in Education and The Department of Education and Science. Ireland.

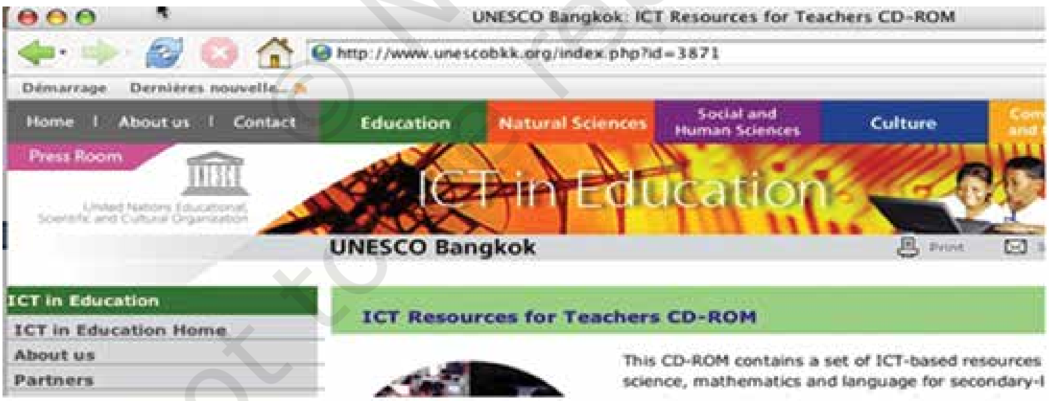
Teacher will find the report a very useful source of information and ideas, with regard to the theory and practice of computer-assisted data logging to enhance practical work in chemistry and physics. The report also addresses other valuable teacher professional development issues in the use of computer technology in teaching chemistry in the classroom or laboratory.

Useful Links

In this section, links useful for ICT use in chemistry are given. The links placed here introduce teachers and learners to the resources available to them. As a teacher, one should encourage learners to read the descriptions provided before moving on to the learning activities. Education research shows that this will help learners be more prepared and help them articulate previous knowledge

Description

ICT Resources for Teachers, the CD-ROM contains a set of ICT-based resources for teaching and learning of science, mathematics, etc., for secondary-level students, including simulations, video clips, interactive learning objects for quizzes, animation, and other kinds of multimedia learning activities. The materials and lesson plans provided here are organised and relevant to subjects. A separate directory is provided to give an overall view of the types of resources available.



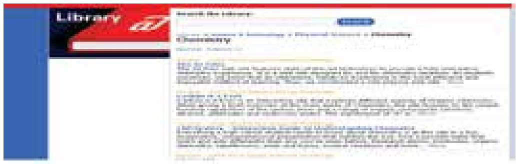
UNESCO Bangkok: ICT Resources for Teachers CD-ROM
http://www.unescobkk.org/index.php?id=3871

- http://www.crocodile-clips.com

Description

This Website provides a number of free sets of simulations which are available to download. It lets you open, run and interact a set of chemistry simulations that have been enabled for use. Incorporating graphic software into chemistry courses has been found to foster understanding of molecular 3D structure, and spatial ability and to promote meaningful learning. Difficulties in learning chemistry are attributed mainly to its abstract, unobservable, particulate basis and to the need for quick movement or transfer across the three identified levels of chemistry understanding-the macroscopic, the microscopic and the symbolic world of chemistry. With the advent of computer graphics software, Computerised Molecular Modelling (CMM), and simulated chemistry laboratories have become tenable. This is a very useful site that provides a simulated chemistry laboratory where you can model experiments and reactions, plot graphs, view mechanisms using 3D animations, view lesson kits designed for various topics in chemistry, and which can then be adapted for preparing your own ICT learning activities in chemistry teaching.

- http://www.thinkquest.org/library/cat_show.html?cat_id=49



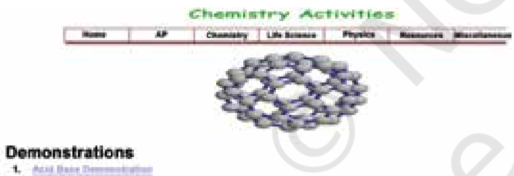
Description

This site features a state-of-the-art technology for a fully interactive chemistry learning experience. The Think Quest library boasts of a number of chemistry textbooks on line for under graduate studies, a list of chemistry eduction-related topics that are designed for student interactive hands-on experience. It is a Website designed by and for chemistry students themselves. An interactive, hands on experience is one way of learning that is effective and great fun. This Website provides a veritable source of information of useful topic sites, for chemistry teaching and learning in an IT-rich environment. It provides among others an exhaustive guide to chemistry on the Internet, which include chemistry textbooks online, Chem Web online, Digital Chemistry textbook, etc. For example, Chem Web 2000, whether for a beginner or an advanced chemistry student, is an excellent site for studying and understanding various topics in chemistry in an interactive manner.

Description

This Website is designed to help the chemistry teacher find useful and deteailed information on various chemistry teaching and learning activities. These activities are displayed under the instructional categories of demonstrations; laboratory investigations; teaching tips, and miscellaneous. Under miscellaneous activities are included involving preparing and using worksheets, internet research exercises; power point assignment; chemical calculations, etc. For the chemistry teacher, familiarity with a range of learning and teaching activities in chemistry is a foremost pre-condition among others, for successful ICT integration into the chemistry curriculum. In addition to providing demonstrations, labs and other information which teachers and users can access in chemistry, this Website also provides useful information on ICT integration and teaching tips.

- http://chem.lapeer.org/Chem1Docs/Index.php



- http://lapeer.org/ChemCom/Index.html and http://chem.lapeer.org

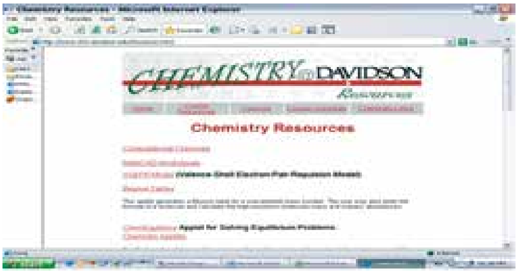
Description

This website is for science/chemistry teachers to share ideas and exchange information. Permission is given to use and reproduce all materials at the site as long as the activties are not sold. This chemistry teachers' resource Website is an easy-access source for a variety of chemistry teaching and learning activities on the internet. There is much more information available, it is just a matter of finding what is relevant to your needs.

Description

This Website is a collection of chemistry applets simulating various chemical systems and experimental systems. It exposes the user to virtual chemistry experiments and exercises. These configurable applets are available for use, and to create new Web pages containing customised simulations and representations of chemical experiments. The chemistry-specific learning activities of this module require of the student knowledge of subject matter content (i.e., chemistry), and a measure of competence in chemistry-ICT integration skills. This website provides the user or student with the invaluable opportunity to review a variety of resource based ICT-chemistry integration activities, for possible adaptation in a given classroom situation. This collection of applets includes a series of tutorials and simulated experiments available for a variety of chemistry topics; 3D visualisation of molecular structure, and generated computational chemistry exercises.

- http:www.chm.davidson.edu/resources.html



Learning Activities and Project Based Learning (PBL)

1. Working with a database

Summary : Application of databases in chemistry

In this activity students are required to create and use databases for storing information or variables in chemistry and then carefully examine these databases to find relationships and commonalities, in terms of, say, structure and the corresponding properties and functions.

Assignment

As a first step, try to prepare an appropriate structure of a database for any chemistry example, into which data can be added. Variables, such as—

- the characteristics of chemical elements in the periodic table;
- the characteristic structures and properties of the functional groups in organic compounds

But before preparing an appropriate database you need to understand some of the relevant steps in problem solving, which include such stages as, design, data entry and modification, etc., and then identify a problem in chemistry that can be solved by a database.

Design and create a database to enter and store chemical information into which you can add data.

Formative Evaluation

- the identification of the chemistry topic(s) suitable for the application of database
- the demonstration of an understanding of the relevant phases of problem solving
- the ability to create or use prepared database to store information and variables, (for example, the characteristics of chemical elements in the periodic table)
- the ability to draw and interpret these databases to find relationships and commonalities in a structured and rational manner.

Other important links for lesson ideas

1- Periodic table   2- Genetic Variation (modelling)

2. Title: Data logging

Summary : The use of ICT tool for the measurement, collection and processing of chemical data.

Experimentation and measurement in chemistry is one of the principal means for guided discovery learning, and for knowledge construction based on experience. Computer aided data logging has given rise to new approaches in chemistry practical work.

The basic parts of a computer aided data logging system or an ICT measurement system are shown here. The system includes: the input (sensors), processor (computer), output (software— graphs, tables, data handling).

A sensor is a device that is able to respond to the physical property of the environment. Sensors detect variables or changes in the physical properties of: sound, conductivity, force, oxygen, heat flow, voltage, pH, light and light gates, temperature, differential gas pressure, barometric pressure, electrical current, angular displacement, humidity, magnetic flux density, blood flow, radioactive decay, acceleration.

A wide variety of sensors exist and they are used for recording data automatically. A list of some of the sensors required for teaching secondary school chemistry are— Temperature Sensor, pH sensor, Colorimeter sensor, High range Temperature sensor, Voltage sensor, Light Sensor, Conductivity sensor, Absolute sensor pressure.

The sensors, interface unit computer and appropriate computer software comprise what is commonly called data logging system.

Assignment

1. A teacher has to find out from a survey of the educational literature available on the Internet, the chief advantages of data logging in chemistry education.
2. Identify and list 20 areas or topics of the school chemistry syllabus in which data-logging equipment has been and can be used.
3. Write two experiments in school chemistry for which a particular brand of data-logging equipment could be used. Conduct an Internet search for a template (or develop one) to illustrate the format to be applied for writing up the details of the experiments. Include lesson plan and assessment scheme and lesson evaluation.

Formative Evaluation

The assessment will be two fold: the first will be based on your knowledge of the elements of an ICT measurement system and what research says about the effectiveness of data-logging in teaching chemistry at secondary level; and secondly, the ability (during contact session) to perform simple computerised measurements on a wide range of experiments in chemistry laboratory work, process the experimental data and draw conclusions from them using the most suitable data-logging system.

Title: Use of ICT in project-based learning in chemistry (Information and Communication in Chemistry)

In an IT environment, students can use ICT–based tools, such as, a word processor or presentation software to report on the results of experiments, present a research project or communicate with other students. Also, for research projects and specific assignments, the Internet can be used as a source of scientific data and theoretical information.

This learning activity is about the integration of project-based learning in an IT environment into chemistry teaching, using the Internet as the learning environment.

Assignment

The two assignments given as examples here are to be carried out individually. The resources needed are— computer and access to Internet.

The two are titled 'Elements in the periodic table' and 'Scientific theories'.

The first assignment, Elements in the periodic table takes the investigative form of asking the student to identify a chemical element in a riddle by investigating the periodic table and seeking information using the Web.

The riddle for such an inquiry is— *"I can be found in batteries and coloured old glasses, but not in pencils anymore, I am known for my high density and I am poisonous who am I?"* (the answer is lead Pb)

The students are asked to identify the element and present information regarding the date, place, and the way the element was discovered. They are also required to present an image or visualisation of the element, its chemical and physical properties and its daily use and applications. Furthermore they may be required to make use of online data including readily available easy-to-use applets to identify and perhaps simulate all kinds of processes and phenomena relevant to the investigation. Individuals or groups of students may be asked to investigate different chemical substances.

The second assignment, Scientific theories is concerned with the complex process of accepting or rejecting a scientific theory. The students may be required to investigate the principles of a given theory in chemistry and to explain why it was accepted or rejected by the scientific community.

In this assignment each or a group of students will receive a different theory. Some theories, such as, cold-fusion and poly-water fell by the wayside, i.e., rejected, while others, such as molecular orbitals, quantum theory, acid-base by Lewis, and Schrodinger's atom model are accepted.

At the end, the teacher may want the students to share the knowledge they had acquired by asking them to upload their projects to the course website for the benefit of all classmates.

Formative Evaluation

The PBL in chemistry may be evaluated both quantitatively and qualitatively. The quantitative component may take the form of a pre- and post-test of students' prior knowledge in the areas to be covered.

The qualitative evaluation may focus on content analysis of the students' projects in which qualitative interpretations will be constructed gradually from the presentation. First, the students' answers to the inquiry based questions will be processed and analysed listing concepts, words and arguments they used. Second, conceptual categories of chemistry understanding will of necessity be generated from the write-ups (to be supplemented by interviews perhaps) to determine meanings and relationships of concepts. Third, the issue of how critical the students were in terms of evaluating the quality and relevance of all information retrieved and the ability to cite and reference sources correctly when reporting will be factored in. Finally, a summary of the teacher's insights into the investigated project will be produced.

Conclusion

Information and communication technologies facilitate worldwide contacts between teachers and students. The Internet is now a veritable source of scientific data and theoretical information and offers a viable means to support authentic learning in chemistry. Discovering the scope of information available over the Web and in other ICT based cognitive tools and how to use it should be part of the undergraduate education of every chemistry student and teacher. In this paper, we have engaged in learning activities that focus, among others, on the integration of the Internet and the World Wide Web as an additional medium for enhancing the teaching and learning of chemistry. For example, simulations can be used to develop understanding of chemical concepts in different contexts, computers can be used as research tools for inquiry-based chemistry projects. The possibilities are endless and can be stretched to limits and depend on a teacher's efforts and imaging powers and also on the collaboration and cooperation among teachers and students. We hope this paper will provide enough material to meet these demands.

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