I O C D

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ChemKnowBase

A new internet-based knowledge resource to support teachers and learners in chemistry

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As noted by Peter Mahaffy, powerful forces are currently re-shaping the teaching and learning of chemistry. These include:

- developments in the science itself and the way that chemistry is evolving new interfaces with other disciplines and new research areas to meet the challenges of the 21st century:
- Evolution in our understanding of how learning occurs;
- The massive impact on all areas coming from computer and information technologies
- And a variety of external forces, including
  - global concerns about energy and water resources and the environment
  - and the need to increase the levels of chemical literacy and public understanding of science

All of these forces are re-shaping both the content of chemistry as a subject to be taught and learned; and the modes through which teaching and learning takes place.

For at least a couple of millennia, since the time of the ancient Greeks, the main mode of engagement has been direct interactions between the teacher and learners taking place in real time. This has been, and still is to a great extent, the age of the classroom and textbook.

The development of correspondence courses by people like Isaac Pitman in the 19th century inaugurated the era of distance education, which took a further step forward when broadcast media, especially television, began to be used to deliver lessons – for example in the UK's Open University around 1970; and these distance education courses were supplemented by supporting materials mailed to the students.

The advent of computers and the internet has created massive new opportunities to further develop and expand open and distance learning. One striking example of this has been the explosive growth of Massive Open Online Courses (MOOCs), such as those provided by the Coursera, edX and Udacity, promising "education for everyone" and available anywhere that the internet can be accessed, even while on the move. We are now seeing another evolution in this field, with smartphones offering further opportunities for accessing knowledge anywhere at any time.

One crucial aspect is that all of these different modes of teaching and learning make use of textbooks or related support materials to supplement the content of lessons delivered directly by the courses. And this is also an area where we can expect to see a dramatic evolution from the classical approach.

Traditionally, chemistry knowledge to support the preparation of lessons by teachers and the learning and understanding of the material by students has involved literally a **know-ledge** – a collection of textbooks on a library shelf.

In the 21st century, the equivalent needed for the age of computers and the internet is a **know-base** – a set of chemistry knowledge resources accessible on the web.

IOCD is developing such a chemistry resource, in the form of a suite of inter-connected elements called ***ChemKnowCore***. These include:

- ***ChemKnowBase***, which I will be explaining in detail in a moment. ***ChemKnowBase*** was conceived by Professor Alain Krief, an eminent organic chemist at Namur University, and he and I are leading the current development work.
- Alain Krief has also been working for a number of years on building an on-line chemistry dictionary.
- IOCD collaborators have already created a number of resources to support distance and open learning in chemistry that are available on or through IOCD's web site – including an advanced course in medicinal chemistry developed by Prof Lester Mitscher at Kansas University and organic chemistry tutorials in Spanish developed by Prof Carlos Rius and his colleagues at the Autonomous University in Mexico City. Recently,

Other planned elements of ***ChemKnowCore*** will include:

- accounts of work by eminent chemists, which is being overseen by Oliver Reiser at Regensburg;
- a database of chemistry experiments being assembled by Burkhard König, also at Regensburg; IOCD has also been involved for several year in supporting the development and use of microscale science kits, originally developed by John Bradley at RADMATE in South Africa and disseminated through the Global Microscience Experiments Project at UNESCO;
- chemistry games, which are being gathered and compiled by Alain Krief;
- and links to other sites offering valuable resources for teaching and learning chemistry – IOCD's web site already carries a number of such linkages, and recently Prof William Reusch of Michigan State University has made his Virtual Organic Chemistry Textbook available for IOCD to incorporate into ***ChemKnowCore***; and Prof David Evans at Harvard has offered linkage to his course on advanced organic chemistry.

IOCD has established a partnership with a young, innovative IT company in Pondicherry, India, to develop ***ChemKnowCore*** and the shell of the ***ChemKnowCore*** web site is already under construction, under the leadership of Atomicka's CEO, Devi Shan. Available components such as the tutorials in Spanish, the medicinal chemistry distance education course and William Reusch's virtual textbook of organic chemistry are being slotted in as the structural development work proceeds.

Entry to topics in William Reusch's virtual textbook of organic chemistry can be through the Table of Contents or via an alphabetical index.

Reusch's book is just one example of a myriad of chemistry resources that are now becoming available on the internet. Indeed, a Google search for 'free chemistry text books' yields more than 11 million results, while a Google search for 'open access chemistry text books' returns more than 1.8 million results. So with all the material out there, is there any need for another web site offing learning and teaching resources in chemistry?

If you inspect what is actually out there on the web, what you find is a very complex, chaotic and confused picture:

- There is a very wide variety of types of materials available, including text books such Reusch's virtual textbook of organic chemistry; courses and course units in aspects of chemistry, ranging from large-scale operations such as the MOOCs to individual items offered by a single teacher;
- The materials available are at a variety of levels, ranging from high school and community college to university undergraduate and Master's levels;
- The materials are presented in a very wide variety of formats, including classical texts: electronic books, web pages, PDF files, videos, and PowerPoint slides;

- The quality is extremely varied and it can be very challenging to know what to rely on. There are eBooks and courses by eminent academics; but also a great deal of material from ill-defined or little-known individuals, groups and organizations; and there are 'Wiki' chemistry sites, but the reliability of material on wiki sites can fluctuate and is questionable.
- Despite the very large number of sites offering resources, overall the coverage of chemistry is incomplete and inconsistent with regard to range, level and depth.
- There is a lack of inter-linkages that can enable searches of topics to be conducted between fields of chemistry.
- And the content is often shaped to a specific national or institutional curriculum or course.

So, it is against this background that IOCD has initiated a programme of work to develop a new internet-based knowledge resource to support teachers and learners in chemistry. Some key features of ***ChemKnowBase*** are:

- It aims to be a comprehensive approach, covering all areas of chemistry consistently at a defined level. ***ChemKnowBase*** is being initiated at the university level, but will eventually be expanded to cover high school level and a version will also be created for the general public aiming to promote greater scientific literacy and understanding. At each level, ***ChemKnowBase*** will provide a uniform, verified, up-to-date account of topics.
- The topics covered will be identifiable and searchable, through a Table of Contents; keywords; and text strings.
- The content of ***ChemKnowBase*** will not be driven by any specific curriculum or course. It aims at extensive, in-depth coverage of the whole of chemistry – providing a global resource base from which any educator can derive a curriculum or course and construct lecture notes and exercises; and in which any student can find in-depth explanations, clarifications, examples and links to further reading to supplement course materials.

The core element of ***ChemKnowBase*** is the TOPIC: Each topic will be developed as a discrete entity by an appointed writer. It will consist of a text that describes and explains observations, theory & mechanisms, gives examples and applications, including real world problems, provides figures and illustrations and incorporates exercises. The text will be accompanied by structures and equations and suitable experiments. Each text will also be accompanied by a list of references to external sources for further reading. And very importantly, each text will include hot links providing jumps to internal, peripheral and external sites.

The internal linkages will be to other elements of the ***ChemKnowBase*** site – that is, to the Table of Contents and to the searchable databases containing the entire collections of texts, structures, references, experiments and so on.

Peripheral linkages will take the user to other components of the ***ChemKnowCore*** suite within which ***ChemKnowBase*** sits, so that the user can look up terms in the chemistry dictionary, read accounts of relevant research, and so on.

The external links will take the user out to other web sites where useful, relevant material can be found.

The construction and development plan for ***ChemKnowBase*** involves a series of stepwise and parallel processes.
Construction will involve a global collaboration of chemists and software experts from academia and industry.
ChemKnowBase will be initiated at university degree level
There will be parallel development of Content, Databases, the website architecture and user interface.
Two vital quality control elements are embedded in the approach to developing the content of each topic:

- Every topic draft submitted will be subjected to peer review to ensure that it is accurate, up-to-date, clear and appropriate in its range and depth of coverage and references and in the breadth

and relevance of examples it provides. With regard to relevance, emphasis will be placed on showing the critical linkages and interfaces of chemistry to industrial processes and products; to other science disciplines; and to tackling contemporary challenges of global and local concern.

- After peer review/revision of content, every topic draft will be subjected to a strict editorial process before being incorporated in ***ChemKnowBase***, ensuring that there is complete consistency in the uses of terminology, abbreviations and explanations.

Pilot Project

The work on ***ChemKnowBase*** is beginning with a pilot project. The IT Element will be developed by IOCD in collaboration with Atomicka. It will include a structure Database (built using ChemAxon tools), and further databases for Text, References and Experiments. Atomicka will also be developing the Website and User interface.

In parallel, the Content Element of the Pilot Project will involve four subject areas. The selected topics (organo-iodine, -fluorine and -lithium chemistry) have been carefully chosen because of the intrinsic importance of each and the multiple relationships that occur between them, providing an opportunity for modelling the development of cross-references and linkages that are a critical feature of ChemKnowBase. A further topic in the pilot group, theoretical chemistry, will allow modelling of a very different textual style, while also providing opportunities for cross-linking with theoretical aspects and insights relevant to the other three areas.

ChemKnowCore will include an extensive resource base of experiments in chemistry. In the pilot project, relevant examples of chemistry experiments will be integrated with each topic being developed for ***ChemKnowBase***.

As previously indicated, the texts developed will be subjected to quality control, involving both peer review of content and an editorial process to ensure consistency. The content element will then be mnerged into the IT superstructure that has been developed in parallel, to produce the pilot website for ***ChemKnowBase.*** Evaluation of the pilot website will involve a range of approaches, including inviting feedback from open access to the site and specific review by a panel of invited reviewers. The results of evaluation will be fed back into redesign of the IT and content elements, as appropriate. After revision, the pilot website will be further developed and will evolve into an expanded website embedded within the ***ChemKnowCore*** Suite and will continue growing as new material is acquired.

As we move forward with this very big and challenging project, we would greatly welcome comments, ideas and volunteers.