Developing historical awareness in university chemistry education

9. Hong Kong Project for Promotion of Nature of Science (NOS) and Science Technology and Society (STS)

Teaching resources for infusing NOS and STSE in 12 science topics for senior secondary school (grade 10 to 12) developed by a team of Hong Kong science educators can be accessed and downloaded at the website http://learningscience.edu.hku.hk.

Each resource package consists of teachers' guides, students' worksheets, PowerPoint presentations and the associated video files. The developers acknowledge the generous support from the Quality Education Fund by the Hong Kong SAR government.

Further information is available from Dr. Alice Wong, Faculty of Education, University of Hong Kong (aslwong@hkucc.hku.hk)

10. Developing Historical Awareness in University Chemistry Education: A Case Study from Eindhoven University of Technology

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Introduction

The knowledge domain of chemistry (and science in general) increases exponentially. In order for our students (chemists of the future) to cope with tomorrow's challenges, some historical awareness of their scientific field is a prerequisite. In addition, nobody will deny that conservation of historical collections and spaces is essential for preserving the heritage of science. Access to those collections is naturally as important for both historians and the general public. Students are a special sub-class of the general audience, requiring special consideration, because they are the professionals of the future. Not all practicing chemists in the forefront of scientific research at present are sufficiently interested in the heritage of their science. It is here that a clear task for educational institutions of chemistry presents itself.

The role of history and philosophy of science in science education has received increased attention in recent years. Different expert views have been presented for the field of physics (Galili 2001), who also paid attention to anticipated institutional difficulties. Historical content of science textbooks, as determined by checklists, revealed that improvements could be made, also within the context of teacher education (Leite 2002). The need to use history of science in secondary school class rooms (Wang 2002) was recognized as well. It was even argued (Solbes 2003) that introduction of history and sociology of science in class rooms can improve the pupil's image and attitude towards science and science teaching, a respectable effort to turn the tide of the negative image of science.

The current paper addresses this task from the point of view of our Department of Chemical Engineering and Chemistry at the Eindhoven University of Technology. We will explain our general campus situation, outline how we addressed the subject of increasing historical awareness in the bachelor and master programs for our students and summarize some results. Conclusions and outlook are finally given in relation to our department's future curriculum. The views given are the personal opinions of the authors, and no claim is made that the didactical model presented here is also the best option in the context of an arbitrary University elsewhere.

The Eindhoven campus

The Eindhoven University of Technology (TU/e) was founded in 1956 as the 2nd University of Technology (then called: Technische Hogeschool, Dutch for Polytechnic) in the Netherlands, next to the one at Delft (founded 1842). After 50 years of existence, TU/e now has Departments such as Chemical Engineering & Chemistry, Applied Physics, Mechanical Engineering, Biomedical Engineering and Mathematics & Informatics. With respect to research output, we are in top-3 of European Union in terms of publication impact factor (http://cordis.europa.eu/indicators/third_report.htm). At the same time, we have seen many educational innovations and an increased the influx of foreign master students.

With regard to our own department, it should be noted that we combine both chemistry (as taught in "normal" universities) and chemical engineering, as taught in the 3 technical universities in the Netherlands. In the context of the subject concerned, it is also relevant to note that we do have neither a History Department nor Humanities in general. There is no science museum. Some historical collections are present in the Chemical Engineering and Chemistry Department, however, but they are owned by individual staff members. Significantly, these are not stored in the basement, but shown in display cabinets in corridors.

Our curriculum

The department curriculum consists of a 3-year bachelor program and a 2-year master program. There are three parallel tracks for the latter: process engineering, molecular engineering and polymers and composites. The didactical model used includes: lectures, practicals, group work, a term paper, an individual graduation project and an external industrial internship. In every year there is room for academic competences (chronologically consisting of a reader, introductory lecture, group discussions, plenary conclusions and submission of a mini-essay). Within academic competences, several areas are incorporated: history of chemistry, history of philosophy, philosophy of science, methodology of science and chemistry in relation to industry and society.

We are convinced that historical awareness should in fact be a widely accepted notion among all professional chemists and chemical engineers. As a logical consequence, it should find part in the curriculum for our students. Given the situation of our University as outlined above, three different options can in principle be chosen.

Option 1. One external specialist

An external expert can be hired to give an optional (or compulsory) lecture on the history of chemistry. There could even be different courses in each of the 5 years (3+2) of the curriculum. An even cheaper option would be to call it history of science, and offer it for students of all departments. Some universities in the Netherlands have chosen this option, but we consider this the worst one, for several reasons. As it depends too much on the person presenting these courses, it is very vulnerable (at retirement the whole system collapses). Moreover there is no embedding whatsoever in existing curriculum of different departments. If, in addition it is optional and given for the campus in general, all ingredients are present to guarantee a minimum of retention in the mind of the future chemist/engineer.

Option 2. Everyone teaching

The second option would be if each and every staff member, in each of his lecture series, would devote significant time to an historical perspective of his own specialization. Depending on the field, some would have to start chronologically in the 17th century; more recent specializations would need less time for an historical angle. Personally, the authors would favor this approach. In the field of analytical chemistry, the 1st author would have liked to start with mentioning the early experiments of Friedrich Kohlrausch (1840-1910) and Mikhail Tswett (1872-1919) and the later ones by Arne Tiselius (1902-1971) and Archer J.P. Martin (1910-2002). Looking back at the earlier work of the latter (resulting in the Nobel Prize for chemistry in 1952) one can say that he was one of the first (bio)chemists working with chemical engineering unit operations, a fact illustrative for the need of scientific analogies in historical context.

In the field of materials science, the 2nd author often refers throughout the courses to anecdotes of which quite a few are given in the short biographies and footnotes in his recent book on structure and thermo-mechanical behaviour (de With, 2006). A more systematic review for the mechanics would probably begin with scientists like Isaac Newton (1642-1727), Jean le Rond d'Alembert (1717-1783), Thomas Young (1773-1829) and Joseph-Louis Lagrange (1736-1813). Thermodynamics would start with Nicolas Carnot (1796-1832), Hermann von Helmholtz (1821-1894) and Rudolf Clausius (1822-1888). For materials James Clerk Maxwell (1831-1879) and Franz Ernst Neumann (1798-1895) immediately come to the mind.

Alas, this second approach in practice would not work either, for two main reasons:

- Regrettably most staff members are unable to put their field of science in historical perspective, even for a student audience;
- More importantly, many staff members are unwilling to devote time to history, because they want all of the allotted lecture time (and preferably more) for the benefit of outlining how their specialization will change the lives of future generations.

Admittedly, it does become increasingly difficult to teach the engineers of the future in rapidly expanding fields of science, resulting in the need for lifelong learning.

Option 3. Academic competences

The bottom-line of our approach chosen is best summarized in stating that creating historical awareness is not the same as teaching the history of chemistry in a series of lectures by an expert historian. Historical awareness in our view is an essential academic competence, best taught in an interactive, hands-on setting using the didactical model of practice-by-doing. In this way, it is embedded in our curriculum and different staff members, some of them rotating, are involved in all 5 years of the Ba-Ma curriculum. The reason for doing so is exactly the same, as the one used for teaching laboratory safety: integrated in actual lab work, rather than as a theoretical lecture concept. We would even go as far as stating that also ethics should be taught in a likewise practical manner, instead of attending a lecture course. Historical awareness is also the best way to make students familiar with the time dimension of science, both backward and forward, and its implications of their future career, where innovation and life-long learning are the key-words for successful science and engineering.

The practical realization in the 3 bachelor years is organized as follows. In the 1st semester, students are given a reader to study. Two afternoons are planned consisting of plenary introduction, discussion in groups, results of which are written down and discussed in final plenary meeting. In the second semester student also make a mini-essay on a related subject, and a guest speaker delivers a lecture on a subfield of chemistry or chemical engineering, from a company background, and in a historical perspective. In a somewhat later stage of implementation, and to improve attention in the first semester, it was decided to have the student write a one-page essay, the subject of which to be chosen from the topics discussed. Three years after introducing the previously mentioned academic competences in the bachelor, it has been decided to introduce similar activities in the master programs, starting in September 2007. Prior to that, there have been a few isolated initiatives introducing historical aspects in the master program: a few term papers and a multi-disciplinary group project.

This paper presents three approaches of introducing historical aspects into the curriculum: academic competences in year 1, project work in year 4, and a term paper in year 5.

A. Academic Competences examples

In the example given, the reader provided to the students consisted of an historical overview about photography, from a chemical point of view (Sheppard, 1927). In subsequent discussion groups, students addressed a number of statements, one of them being the following citation:

"The history of photography and the history of chemistry are, naturally, closely parallel. The relationship is much closer than between physics and photography." (Sammis, 1941)

Elaborate discussions resulted, because all involved realized that the statement given was not just a binary question. The discussions in the groups seemed to follow different roots, for example the historical role of optics, relative to chemistry, the definition of chemistry and physics (now and in the past), research specialization throughout the centuries, what does “PhD” mean, even up to topics such as “why did I choose to study chemistry” and the archetypal difference between a typical chemist and likewise physicist. The purpose of these discussions is learning to discuss, use arguments, distinguish between facts and opinions, and realize there’s usually 2 or more sides to a medal. If, after meaningful discussions, the students find the question of the original citation irrelevant or even stupid, so be it, as long as there are meaningful discussions about historical aspects.

Another example of an historical case is that of the life and works of Fritz Haber (1868-1934), based on the article “Friend of Foe of Mankind” (Perutz, 2000). Discussion items in that case were some of Haber’s career decisions in the light of the fact that he enabled both large scale manufacture of artificial fertilizers but also stimulated advances in chemical warfare in WW I. It was not surprising that professional ethics proved a major discussion point in that case. To give an example, consider the following fact: it is highly likely that Haber’s wife committed suicide because of her husband’s involvement in chemical warfare, and that Haber left home the day after, to serve on the east front.

The topics mentioned above provided an example drawn mainly from a technical and societal point of view, respectively. In generally it was tried to divide the topics over these two view points. Other topics discussed were:

- Polywater (Allen 1973): fraud or the way science should act?
- Limits to growth (Meadows 1972): will science and technology prevent that world perishes before 2100?
- From atom to molecule (Vekemans 2004): could the controversy between the atomic weights and equivalent weights have resulted much earlier in a solution?
- Electrolytic dissociation (Berg 2003): why was the competing theory of Armstrong defended and defendable for such along time against the Arrhenius theory?

Although the emphasis for each of the topics is obviously different, in all cases technical and societal aspects arise. Regarding the time dimension, in all cases presented the students have been faced with the fact that the answer to questions such as the ones given may be different at different points in time or in a different context.

B. Group work example

Project group work is a compulsory unit (8 ECTS) in the Master's degree. Every project has a unique subject, ranging from feasibility studies, prototype designing (build and/or test), scenario studies, business plans or combinations thereof (http://www.ifp.tue.nl/). Here, we outline just one of the many subjects from the past. A project was carried out by a group of students (originating from the Netherlands, China and Portugal). The group was coached by a tutor, a PhD student from France. Aim was to investigate sustainability of photographic image carriers in historical context in the period between 1800 and 2000. In short, the purpose of sustainability can be described as follows:

Sustainability seeks to provide the best options of a process/product in relation to human and natural environments for both present and future generations. (Brundtland, 1987)

Resources were books from the libraries, texts from the internet and importantly a visit to the excellent photography museum in Antwerp (http://www.fotomuseum.be/), Belgium with a large collection of old cameras and conserved images from the 19th century history of photography. From the composition of the project group one may conclude that the group's challenges were not limited to photographic history, but also of a multicultural nature, another educational goal. The project outcome was a website (http://students.chem.tue.nl/ifp12). The sustainability was determined using the Eco-99 concept of a Life Cycle Analysis LCA (van den Berg, 1995 and Goedkoop & Spriensma, 2001). The Eco-99 value of a product/process quantitatively takes into account all materials and energy used. The lower the Eco-99 value, the more sustainable a product or process can be considered. A high contribution for example can be due to depletion of fossil fuels, energy-intensive production methods, recycling problems and poisonous materials. The results of the study indicate that sustainability of the photographic image carrier has enormously improved during the past two centuries, although it is unlikely that sustainability has ever provided an important driving force for innovation. This observation in itself is significant. The sustainability concept in historical context proved an excellent binding factor to increasing historical awareness in a subject as multidisciplinary as photography. One might even argue that sustainability is by definition all about historical awareness of science, society and natural resources

Another example of a multidisciplinary project is the following: a group of Eindhoven students, designed, constructed and tested a solar energy refrigerator driven by a Stirling engine, in collaboration with a US company and another group of students at the National University of Singapore (Reijenga et al, 2003).

C. Term paper examples

There were two reasons to elaborate on group results mentioned above. First, due to the complexity of the LCA methodology the results are only semi-quantitative. More importantly, the results are potentially interesting for a broader perspective and audience. Keywords were: sustainability, chemistry, photography and historical context. One of the students participating in the group mentioned, Almerinda Monte from Portugal, decided to make a 6 ECTS optional term paper. Resources for her work, in addition to the Antwerp museum were 30 books (e.g. Hirsch, 2000) and journal articles and 25 internet sources. Several of the latter were excellent, for example the website of the Daguerreian Society (http://www.daguerre.org/). Internet may have a bad reputation for containing a great deal of pseudo-science or worse, but it should be emphasized that many museums have excellent virtual counterparts on the internet, such as the one about Nicéphore Niépce (http://www.nicephore-niepce.com/). Obtaining detailed quantitative information about chemical ingredients of all image carriers, including their manufacture and processing was a significant amount of work. The techniques investigated are a representative selection of the many discoveries in the history of photography since the early 1800's. The techniques chosen are those invented by Nicéphore Niépce (1827), Louis Mande Daguerre (1837), William Henry Fox Talbot (1840), Frederick Scott Archer (1851), Richard Leach Maddox (1871), George Eastman (1935) and also includes CCD (from late 70's).

Bearing in mind that the boundaries were set around the image carrier, the trend over the past 200 years can be summarized as followed: Technical innovations have been driven by the need for lower costs and better specifications (film speed, color depth, resolution and miniaturization). At the same time, but as a secondary result, the Eco-99 indicator for sustainability has improved a million-fold. We then changed the boundary conditions to include only the camera. Sustainability deteriorated dramatically in time, largely due to increased complexity and hundred-fold decrease in expected lifetime.
The generalized conclusion from the previous example would be that there is need for a broader view on technical innovations, and for placing them in historical perspective.

More details on the photography example can be found in the book resulting from this term paper (Monte 2007), or by contacting the corresponding author. The sustainability theme as a common denominator has also been successfully used for other term paper subjects as well, e.g. sustainability of food preservation in historical perspective.

Conclusions and Outlook

We have outlined different options for increasing historical awareness among students of chemical engineering and chemistry at our department. On the one hand, historical aspects are considered essential academic competences, and included as such in the academic competence course that is part of the compulsory program. In the bachelor curriculum, 3 ECTS units are reserved for that. Future master program will include 6 ECTS of academic competences. Interactivity and hands-on practice-by-doing are key elements in the didactical model.

Resources for activities mentioned in this paper were manifold: historical collections in museums or those owned by individual university staff members, journals, books, internet resources and even virtual museums.

Next to this, it has been shown that the optional part of our master curriculum offers ample opportunities for incorporating historical aspects into contemporary chemistry education. Finally, two important aspects are worth mentioning:

First, it helps to have a common denominator linking past with present and future science. Ours was sustainability, but there are other options, such as innovation (generally applicable in science) or advantages/disadvantages of scale (specifically important for chemical engineering). Second, in our opinion, every teaching scientist has the moral obligation to put his area of specialization in historical (and societal) perspective.

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