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Teaching Thermochemistry with ICT to Students and Inservice Teachers

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Introduction

The influence of the learners' science background on the use of ICT seems to have not been much documented. However, it would be interesting, as far as inservice teacher training is concerned, to understand the differences between the way students and their teachers learn science (Calik & Ayas, 2005). Teachers have a much higher background than their students, and the way they may be taught chemistry (if they are physicists for example) is important to be known in the case of inservice training. More specifically, teaching inservice teachers the way to change their practice in teaching chemistry by means of simulations is a challenge that is astonishingly difficult to fulfil.

At the secondary level, simulations in chemistry have been much developed in the fields of titrations, molecular representations (particulate model of matter, stereochemistry, collisions, etc.), and for the use of the periodic table. As a case in point, teaching thermochemistry with ICT seems to have concerned little innovators and researchers in education. Such a field is not much appreciated by teachers who seem reluctant to work with the concepts of bond energy and heat of reaction, although education research has been done in this field (see Boo, 1998 and ref. herein). Nevertheless, a lot of interests may be found, and such a topic has (i) societal values in relation to combustion of hydrocarbons, and (ii) academic interests as it concerns fundamental and difficult concepts in physics: energy, and in chemistry: bonding.

The aim of this work is to describe the content and the use of a new simulator that concerns teaching thermochemistry at the upper secondary level. This work has also explored the influence of the background of learners when using such a simulator. It is expected that information for inservice teacher training to use ICT can be derived from this work.

Theoretical framework

Comparing the activity of different learners such as teachers and students can be done by finding the facets of knowledge that emerge during discussions. Facets represent elements of knowledge expressed in a declarative way (Galili & Lavrik, 1998). They are observable. They offer the possibility to list what a given person has involved about a concept. Although s/he may know more than what is on the list, such a list is an interesting description of the ideas about a given knowledge related to a concept that has been involved in a given situation. Facets can be grouped into topics that are close to the teaching objectives of the task. We found convenient to choose few basic concepts involved in the task (energy, chemical bond, heat, temperature, and system), and group the facets related to these concepts when they are involved independently, or in relations to each other.

Simulators are usually developed to imbed concepts in situations on which learners may act and interact. In the following, we consider three categories of concepts. Concepts that have been created for the simulation and that are not proper scientific concepts (named SS – Simulation Specific), such as the fact that atoms representing molecules may be red or black. Other concepts belong both to simulation and science (named SC – Simulation and Chemistry) such as the fact that atoms are bonded within molecules. Finally, science concepts may be imbedded in the simulation although they are not directly visible on the screen such as the heat of reaction (named CS – Chemistry Specific). We believe that constructing the latter

is more difficult than those of the two other categories, and that observing learners to use them is considered here as learning.

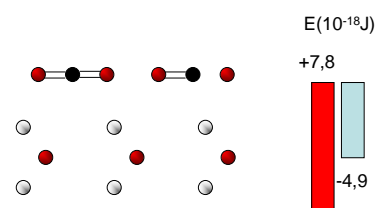
Research questions

The following questions are to be answered in this research. Which facets of which concepts are involved in learning thermochemistry? How the differences of background between learners appear in terms of facets? Can the concept of the CS category be involved during learning, and how the background of the learner influences the way the corresponding knowledge is involved with the use of ICT.

Method

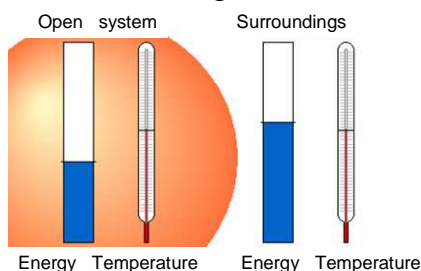
A simulator devoted to thermochemistry teaching has been developed and is briefly described below. It has been involved in a task for 17 year old students. This task was tested during a real teaching sequence, and took place in a computer room, with 16 pairs of students working with computers for 60 min. Two pairs of students were video recorded and the transcription of their dialogs analysed. The written productions of the two pairs were in agreement with those of the 14 other pairs. Separately, two pairs of inservice applied physics teachers (with 5 to 10 years of teaching experience) were involved in the same task. A videograph analysis of the four 60 min videos led to the facets involved by the 8 learners. Moreover, a categorization of the concepts they all involved into SS, SC and CS categories was done. Each time, the quality of the videos was good enough to tell whether the concept was mentioned while learners consulted or not the screen of the computer.

The task that involves the simulation was imbedded into a three parts scenario that made learners almost autonomous. During the first part, learners dealt with a microscopic representation of the reaction of one molecule of ethanol C_2H_5OH with three molecules of oxygen O_2 . The animation simultaneously displayed the successive breaking of each chemical bond



together with the rise of the corresponding energy (left bar in the figure) of this microscopic chemical system. Then, the reorganisation of the now independent atoms to produce two molecules of carbon dioxide and three molecules of water was shown. Finally, the following creation of chemical bonds with the corresponding decrease of the energy level (right bar in the figure) of the system was represented. The figure correspond to the part of the animation where bonds are forming: three carbon oxygen bonds are already formed (corresponding to $-4,9 \cdot 10^{-18} J$), and one more carbon oxygen, and six hydrogen oxygen bonds are to be formed. Following the simulation, students were asked different questions that led them to propose a definition of the energy of a chemical reaction.

In the second part, the learners were asked to propose the simulation that would occur if the reaction of one molecule of hydrogen H_2 with one molecule of chlorine Cl_2 that gives two molecules of hydrogen chloride HCl was simulated. They were also asked to guess the energy involved during the reaction, the values of the bond energies being given. They could check their anticipations with the simulation. They were then proposed to do the same with the combustion of methane CH_4 .



In the third part, a macroscopic point of view of the $H_2 + Cl_2$ reaction was then studied in term of mole quantity (and not molecules quantities). The qualitative evolution of the temperature and energy of a $H_2 + Cl_2$ system was studied in two cases: (i) isolated system and (ii) open system (case

of the figure). In both cases, the temperature and the energy of the surroundings were considered. Finally, the relation of the heat of reaction Q_r with the transferred energy ΔE and the progress of the reaction ξ ($\Delta E = \xi \times Q_r$) was quantitatively studied in non stoichiometric cases. As this relation tells, this teaching sequence is scientifically limited to the variables ΔE and Q_r , and the concepts of enthalpy ΔH , Gibbs energy ΔG , or the standard states were not considered.

Results and discussion

An a priori analysis had anticipated 20 episodes to complete this task. Each episode would correspond to the treatment of a given idea. Students required 22 and 20 episodes respectively, whereas teachers required 25 and 24 episodes (although the latter skipped two questions of the task). A total of 135 different facets were observed, 41 and 35 for students and 71 and 76 for teachers (many facets were observed with each pairs of learners, and/or several times). The students seem to have limited the work to the minimal work prescribed by the task whereas the teachers did more than expected. The extra facets involved by teachers correspond to extra information about each concept, mostly resulting from the mobilisation of prior knowledge belonging to the difference of background. In each part of the task, the scenario had preliminary (easy) questions (for example to get data from the screen), followed by a question where an important concept had to be constructed. The extra teachers' facets appeared mostly in the latter questions.

Students and teachers involved approximately the same number of SS and SC concepts with or without the screen but an important difference appeared with CS concepts: 11 and 9 for students, and 28 and 24 for teachers with the screen, and 10 and 2 by students, and 25 and 44 times by teachers without the screen. This numbers show that teachers were able to construct knowledge directly with the screen, even with concepts that do not directly appear on it, whereas students needed to have time to work on paper to do the same job.

Conclusion

The innovative simulation using ICT to teach thermochemistry that is described above allowed students involving the concepts which are the aim of teaching. This can be interpreted as a validation of the innovation. Training inservice teachers with the same tasks as students do not reduce them to students' activity. Their higher backgrounds were involved in the task in scientifically demanding questions, more often than in preliminary, simple, or technical questions. The explanations that we may give to these teachers, during their training, can be done directly on the screen, but these teachers have also to be taught that their students need a different working practice. Students seemed to need to have less work on the screen and more on paper, specifically for the concept that are not explicitly represented by the simulation.

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