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PROMOTING RESEARCH-LED TEACHING OF CHEMISTRY

Once more about the results of 2006 PISA

Analysis of student performance in different areas of science in the 2006 PISA (PISA 2006) showed that Hungarian students demonstrated relative weakness in being able to identify scientific issues, in knowledge about science and in using scientific evidence (Table 1.). However, they got 29.2 score points higher in the area of "Physical systems" (measuring factual knowledge of physics and chemistry) and 14.2 score points higher in the area of 'Explaining phenomena scientifically' than the average of their own combined science results (504 score points). These data indicate that the emphasis of the teaching and learning process in science in Hungary traditionally had been on knowledge and understanding, rather than how evidence for scientific ideas is gathered and evaluated. The ability of our students in the areas of 'how science works' and 'how scientists work' was unsatisfactory. This raises issues about the relationship between society and the scientific community which, in part, has contributed to the spread of pseudoscience. The analysis states: 'A student who has mastered a scientific theory but who is unable to weigh up evidence, for example, will make limited use of scientific life'. Therefore it was suggested that we 'need to consider the ways which they acquire wider scientific skills' (ibid.). Since then our students' mean performance on the combined science scale dropped below the average, causing even more concern among experts and decision-makers (PISA 2012).

Table 1. Hungarian students' performance difference between the combined science scale and each scale in 2006 PISA (science score: 504)

Competencies		Knowledge about science	Knowledge of science	
Identifying scientific issues	-21.3	-11.9	"Earth and space"	+8.6
Explaining phenomena scientifically	+14.2		"Living systems"	+5.2
Using scientific evidence	-6.9		"Physical systems"	+29.2

Other problems of teaching and learning science in Hungary

The problems of teaching and learning science in Hungary have produced symptoms similar to the ones described by Peter Childs (Childs, 2009). The results of our investigation into the reasons (based on the evaluation of 1033 questionnaires filled in by Hungarian science teachers, meta-research of the literature and many other data available) were published and widely discussed in Hungarian in 2008 and 2009 (e.g. Kertész, Szalay, 2009). They showed that, as in several other countries, science teachers work under significant constraints in terms of available time, lab assistance, external support and funding. Quality control of the teachers' work was largely superficial in those times. Therefore, statements in the science curriculum about competence-based education and active learning had negligible effect on everyday teaching. Since then there have been several changes in the conditions in terms of regulations, curriculum and finance. Although the changes in the curriculum were made with the intention of reducing the content, teachers have not fully grasped the idea that they are expected to teach less content while paying more attention to the development of other scientific skills. Teachers' time remains precious and they need time and support to understand why changes to teaching methods are needed and to develop new skills that this demands. Further, the statement that '...much education research is never read by practitioners and even less is applied' (Childs, 2009) applies in Hungary. In order to help this process, teaching methods that have produced promising results in other countires have to be introduced, tried and tested in Hungary and the results should be discussed and published by the researchers.

Inquiry-based science education (IBSE)

One approach to the development of scientific skills might be the 'inquiry (enquiry)-based science teaching (learning) methods (IBSE). While there are other approaches, IBSE has been widely discussed in the literature (e.g. Minner at al.) It has also been propagated by the European Union Framework Program 7 (Fp7) The author has participated in two of those FP7 projects, titled Mind the Gap (http://uv-net.uio.no/mind-the-gap/about/index.html) and S-TEAM (http://www.s-teamproject.eu/).

mind the GAP   S-TEAM FIRING UP SCIENCE EDUCATION

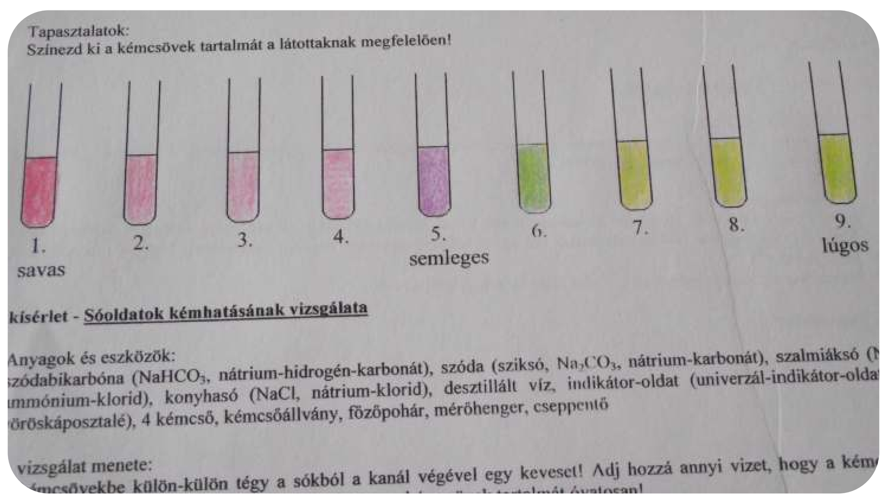
First steps of the introduction of IBSE in the teaching of chemistry in Hungary

The author began spreading the idea of using IBSE on continuous professional development courses organized for chemistry teachers. One hundred and ten teachers have been participating in those courses since 2011. Each was asked to transform traditional 'step-by-step' instructions for students' experiments into 'mini investigations' where students, working in groups, design and evaluate the methods used and data obtained. Alternatively, teachers could devise new investigations. The edited versions of 20 student sheets and teacher guides (including 2 sample materials produced by the author) were published on a website in Hungarian and are free to use (http://www.chem.elte.hu/w/modszertani/fellap.html). Some were tried and tested in schools or in thematic summer camps organised for students. A few examples of the titles of the student sheets and the teacher guides, and the questions investigated by the students are as follows:

1. **J. Balázs, K., Oláh, G., Szakmány, Cs.: 'Changing and unchanged (Physical and chemical equilibrium)':** Some years ago many people received warning e-mails not to eat Mentos candies after drinking coke, because it is very dangerous. According to the letter, a boy's stomach exploded thank to the huge amount of gas formed from the reaction of these two materials. The statement was illustrated by shocking photographs. Could this be true? (Fig. 1.)
2. **Baloghné Pálfy, Zs., Borbás R., Magyar, Cs., Nagy, R., Szalay, L.:** 'The iron tooth of corrosion (Corrosion of metals)': The leftover of a lasagne dinner remained in a stainless steel oven tray was covered by aluminium foil and put in the refrigerator. Overnight small holes were formed on the aluminium foil, where it was touched by the lasagne. Why do you think this happened and why so quickly?
3. **Györe, H.:** 'The blue plum that is red when it is green (Natural acid-base indicators)': You have got 0.1 mol/dm^3 HCl solution, 0.1 mol/dm^3 NaOH solution, red cabbage indicator, ion-exchanged water, Pasteur pipettes, a 10 cm^3 measuring cylinder and 9 test tubes. Design an experiment when you make a pH scale in the test tubes and determine the pH of the household materials that you find on your tray. (Fig. 2.)
4. **Szakács, E.:** 'Acceleration race a'la chimie (Changing the rate of chemical reactions)': When you add acid to sodium thiosulfate solution, a pale yellow colloidal sulphur forms in it. Perform the experiment and then try to accelerate and later to slow down the reaction. You have got the necessary solutions, ion-exchanged water, two dropping pipettes, a dark blue tile and a spirit burner on your tray.
5. **Nagy, M.:** 'A drop in the sea (Amount of substances, surface tension, intermolecular bonds)': Try to think of methods how you could determine the volume of a drop of water by using just ion-exchanged water, two beakers (or glasses) and a Pasteur pipette. Determine the volume of one drop of ethanol too. Why do you think the two volumes are different? Calculate the number of molecules both in one drop of water and in one drop of ethanol. How confident are you in your results? How could you increase your confidence?
6. **Szalay, L.:** 'The Janus nature of hydrogen peroxide (Oxidation numbers)': Look at the 6 different balanced equations in your homework, each containing hydrogen peroxide as a reactant. Try to find a relation among the products and the role of the hydrogen peroxide in the reaction (i.e. whether it was an oxidising or a reducing agent). How could you decide whether the hydrogen peroxide is an oxidising or a reducing agent when it reacts with the chemical that you find on your tray? Apart from the chemicals, you can only use a test tube, a box of matches and a splint.
7. **Hanga, I.:** 'The orange and the sciences (Vitamines, redox titrations): Each effervescent tablets that you find on your tray contains 60 mg vitamin C. It is known that the vitamin C reacts with iodine. Dissolve one tablet in a glass of water, pour some starch solution in it and stir it. Then add Lugol's solution to it drop by drop (while continuously stirring the solution) until the colour change of the solution is permanent. Make notes about your observations and try to explain them. Design an experiment to determine how much vitamin C is in 25 cm^3 of freshly squeezed orange juice that you find on your tray. How could you determine how much vitamin C is in one orange? How confident are you in your results? Why? Assuming you can get 64 cm^3 juice from an orange, what do you think is healthier to have: one of the vitamin C tablets that you used for the experiments or that orange?

Figure 1.: Trial of the student sheet 'Changing and unchanged (Physical and chemical equilibrium)' in a thematic summer camp.

Figure 2.: Trial of the student sheet 'The blue plum that is red when it is green (Natural acid-base indicators)'.The pH scale made by using red cabbage indicator and part of a student's note.



Does IBSE work?

A thesis was written by a teacher trainee summarising the review of the literature and the experiences of a pilot (Rákóczi, 2010). Two student sheets and a teacher guide were written and tried with 3 different groups of students (Fig. 3.). The students had to design two experiments, modelling either the self-heating or the self-cooling cups that can be bought from automats providing drinks, e.g. hot chocolate or ice tea, see http://www.miamz.fr/test/test-caldo-caldo-les-boissons-autochauffantes-1398/. Heating or cooling happen because of the exothermic or the endothermic dissolution of two different salts ($CaCl_2$ or $Na_2S_2O_3.5H_2O$). The groups of students saw a brief advertisement video explaining how to get the cups work. The student sheets also contained a drawing showing what is in the different compartments of the cups. Each group of students was given an amount of one of the salts, water, a suitable size beaker, a measuring cylinder, a stirring rod and a thermometer. They were asked to design a model experiment to illustrate and help explain how the cup heats or cools the drink that it contains. They were also asked to make calculations, to decide whether the cup could heat up or cool down the drink to the temperature promised by the advertisement. Further, they had to consider and discuss the environmental aspects of using these cups. The conclusion of the three trials was that the tasks proved to be very motivating, but much more difficult and time-consuming than expected.

Figure 3.: Trials of the student sheets that required to design an experiment modelling either how the self heating or the self cooling cups work.

Further plans

There are insufficient data at present for critical analysis to publish an evidence-based evaluation about the pilots. A more extensive research, led by the author, has just started. It is part of a national project (titled: National coordination for the renewal of teacher education; No.: TÁMOP- 4.1.2.B.2-13/1-2013-0007). One of its aims is to develop materials to help initial and in-service teacher training. We intend to apply pre- and post-tests, as well as control groups to investigate the possible effects of using IBSE methods on the development on the students' scientific skills and their attitude toward science.

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