Simulation of classical inorganic analysis on-line
- How do the students react ?

Jens Josephsen and Agnieszka Kosminska Kristensen
Department of Life Sciences and Chemistry, Roskilde Univeristy, Denmark
phjens@ruc.dk

Introduction

Laboratory exercises, investigations, and experiments are invariably included in university chemistry teaching. The learning of empirical facts, chemical procedures and methods in chemistry depends heavily on the experience, which may be obtained from such teaching activities[1]. Experimental work in teaching is, however, both expensive and time consuming, and may often consist of students simply following a recipe, while struggling with the capacity of their working memory[2].

Classical qualitative and quantitative analysis of relatively simple soluble salts or co-ordination compounds with inorganic ligands only, has for a long time been part of introductory inorganic chemistry in spite of the fact that professional chemical analysis currently is far more advanced than chemical separation and identification reactions in test tubes and volumetric analysis. The reason to keep and use such an "anachronistic" element in teaching is first of all that this type of simple and classical procedures has a great learning potential. At this university, the course also includes a 20 hours laboratory investigation where simple soluble inorganic salts, in solution or in the solid state, containing common p-block anions (of B, C, N, P, O, S, halogens) and alkali cations and/or ammonium are identified and quantified. The aim is

1. to increase the students' acquaintance with simple semi-micro techniques used to follow simple reactions and the principles of classical quantitative, mostly volumetric, procedures
2. to increase the students' experience of the physical and chemical properties of common inorganic compounds.

To pursue such aims the experimental work should be integrated into and supported by other activities. The use of pre- and post labs has been one way of improving teaching[3,4]. Virtual investigations[5] seem to be a promising kind of tool, and one such teaching element has recently been introduced in the course.

Methods

An interactive, self-instructive simulation of this laboratory investigation has been developed. It was designed from a constructivistic point of view for use on a web-browser platform. The procedures in this electronic simulation follow the laboratory manual, which may be at hand when working with the simulation. The students are thus offered three different, but closely related learning resources to reinforce each other: the laboratory investigation, the computer simulation of it, and written problems involving the same chemistry to be solved by the paper-and-pencil method.

Three recent classes of students (42, 34 and 18 students respectively) were introduced to the programme and were working in pairs for an hour. All students filled in a questionnaire, and some students were further interviewed. The two last classes further took a written 15 minutes pre- and post-test (the same questions before and after the session). 4 pairs of students were video observed during the session.

Results

The students appreciated to work with this simulation because they understood its purpose and acknowledged its relation to other parts of the teaching set up. They tended to enjoy working with it, they found it motivating, and they believed that it created a lot of experience which they thought that they would remember more easily. They experienced the simulation as a time saving way to extend their chemical experience with simple salts and the laboratory procedures of this classical analysis scheme. In the laboratory they often make procedural mistakes, which implies a time consuming reproduction to reach the same stage of the procedure; this reproduction is much faster in the simulation and saves time. In addition, the speed of the simulated laboratory procedures allow for the "analysis" of more unknown samples than in real time experiments, thus creating more experience. The simulation apparently inspired students to reflect on the chemical contents. "*It helped me to think in a chemical way";* this is not easy for the inexperienced student working in the laboratory, because his working memory is occupied by following the procedures.[2,6]

Furthermore, it was found that the programme (in agreement with intention) actually initiates a dialogue among the co-working students, thus creating premises for a better understanding of chemical concepts, principles and methods. The construction of knowledge was demonstrated through the video recordings, and most students felt that they have learned a lot from the programme - and could learn more by using more time with it. The access via the internet was also appreciated, since "*you can sit at home and practice in the laboratory ".* The pre- and post-test results revealed that the majority of students significantly increased their confidence with the laboratory procedures and stoichiometry (both of which areas was trained through the programme), and a better grasp of some relevant chemical concepts.

Conclusion

The study clearly indicates that the students acknowledge the learning potential of the simulation programme. They state independently (they were not hinted by a question about this aspect), that it is a valuable *supplement* to real laboratory work and other parts of the teaching. The simulation seems to diminish the problem that the working memory is often overloaded in the laboratory; the absence of overload then makes thinking possible and stimulates reflection. On the other hand, the students stress the fact, that a *simulation cannot replace laboratory work*. The authentic aspect apparently plays an important role to the students, who acknowledge that real experiments give a far more complete experience of reactions and other properties of compounds and mixtures. In that respect the simulation cannot be used as a pre-lab, but certainly as a post-lab and an in-between-lab. The simulation was generally motivating, creating attention towards the subject matter loaded with (necessary) empirical facts which should eventually be learned by heart; normally many students consider the memorisation of empirical facts to be dull and difficult. The students didn't consider the programme to be too simple or too difficult, because it simulates the actual laboratory procedures and techniques quite closely.

It was further evident, that the interactive form of the simulation initiates a dialog among students. The feed-back from the programme and the fellow student support the verbalisation of the student's conceptions and understanding of procedures and concepts, thus functioning as a facilitator of the individual learning processes. Virtual investigations which are thoroughly co-ordinated with other activities certainly may be a valuable teaching and learning tool.

Implication for education

Interactive self-instructive IT- resources may play an important role as a supplementary tool in teaching and learning. Students as a group appreciate a multitude of learning resources if they are nicely co-ordinated and adapted to each other; the individual student prefers an individual mixture of such co-ordinated resources. Laboratory investigations of a certain length and complexity may benefit from an accompanying simulation of the investigation as a supplement. A simulation programme of a laboratory investigation in particular leaves – often in contrast to the investigation itself - capacity in the short term memory[2,6] to consider and verbalise what happens and what can be concluded from the experiment. Working in pairs with such assignments supports the dialogue and activates the constructive learning processes.

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