Implementing Inquiry-based Learning in Chemistry Teacher Education

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Abstract

A main learning outcome of chemistry education for students at school is gaining competences regarding realising problems, developing hypotheses for solving these problems and therefore planning experiments for verifying or falsifying these hypotheses. In the field of gaining scientific practical skills, regarding problem solving abilities, possible tasks are inquiry-based experiments. Students have to solve a problem by using self-developed experiments. For developing pedagogical content knowledge, a good content knowledge is necessary [1]. Bearing this in mind, teachers have to have scientific practical skills to engage students in investigations, discoveries, inquiries and problem-solving activities.

A main element of university chemistry studies are laboratory classes. During these mostly fixed "recipes" are used. The students won't get much encouraged to think about these experiments and won't develop ideas of nature of science and scientific investigations. Thus there is a demand for implementing inquiry-based learning in chemistry teacher education at university [2]. This research project puts open inquiry-based experimental tasks in all parts of chemistry studies (i.e. general, inorganic, organic and physical chemistry).

In this contribution we present exemplary learning settings which have been implemented in the chemistry curriculum at the University of Flensburg to foster future chemistry teachers´ open inquiry competences in science.

1. Introduction

In contrast to usual laboratory classes at universities, everyday materials can be investigated in inquiry-based learning experiments. This easily catches students at school as well as students at universities. Implementing these experiments in future chemistry teachers' education can improve the quality of teaching [3]. Especially future chemistry teachers complained about the big difference between teaching at university and teaching at school regarding the topics and use of them for their own later teaching [4,5]. Furthermore it could be proofed, future chemistry teacher are less interested in chemical topics than chemistry students at universities, but in the same way interested in linking chemistry to everyday materials [6]. They don't see the use of abstract topics in chemistry, and by implementing inquiry-based learning experiments they're getting more easily involved.

In this work two different inquiry-based learning experiments from two different areas of chemistry are introduced. The first example from inorganic chemistry deals with a commercially available stink bomb, while the second example belongs to the field of organic chemistry and is about investigating different kinds of fabric to compare with students own clothing. Future chemistry teachers have to develop their own ideas for investigating these materials, which hopefully leads to a similar setup for their own teaching at school.

2. Theoretical background

Inquiry-based learning experiments are the counterpart to the traditional way of teaching [3]. Usually, laboratory experiments are standardised and the conclusions are no surprise to the students. Conducting their own research is more interesting for the students and helps to develop their research skills. Especially problem solving abilities are requested and developed.

Therefore inquiry-based learning experiments integrate teaching and research. Students have to follow their own decisions and no strict 'recipes' are used. By discussing their efforts with their teachers they're already real researchers.

3. Investigating the ingredients of a 'stink bomb'

Commercially available stink bombs contain a solid and a bag with liquid in an outer bag. To start the reaction and thus the smell, the inner bag has to be destroyed. The solid and the liquid start a reaction with gas releasing. At some point, the outer bag bursts from the increasing pressure and it starts smelling like rotten eggs.

Fig. 1. Commercially available stink bomb.

Students' task is the investigation of the educts and the products and explaining the occurring reaction [7]. Therefore they have to analyse the solid for its containing cations and anions which turn out as sodium, sulphide and hydrogen carbonate. The liquid content in the inner bag turns out as an acid with pH around 1. Anion analysis delivers citric acid as result. Quantitative analysis by titration confirms a concentration of 20 % citric acid.
In the next steps, the products are in focus. After thinking about the possible reaction(s), it is easy, to confirm the presence of carbon dioxide and hydrogen sulphide with suitable experiments. Finally, the reaction schemes can be set as:

$$3\ NaHCO_3 + C_6H_8O_7 \rightleftharpoons Na_3C_6H_5O_7 + 3\ CO_2 + 3\ H_2O$$

$$3\ Na_2S + 2\ C_6H_8O_7 \rightleftharpoons Na_3C_6H_5O_7 + 3\ H_2S$$

In addition, regarding the toxicity of hydrogen sulphide, the carbon dioxide is just to get the bag bursting at a level below dangerous amounts of hydrogen sulphide. At last, a quantitative analysis of the hydrogen sulphide can be carried out by a reaction with iodine.
The whole experiment can be done by students after learning about inorganic analysis of cations and anions and some knowledge about acidic and basic solutions.

3. Investigating fabric and clothing

This experiment employs an infrared (IR) spectrometer, usually available at every university. By using an ATR-IR spectrometer (attenuated total reflection), no further sample preparation is needed. This method is non-destructive and therefore the best choice for research at peoples clothing.
Polymers like cellulose (e. g. from cotton or hemp) and silk are made by nature, while lots of polymers used for fabric nowadays are man-made, e.g. nylon, a polyamide.
Cellulose and silk are very different, the first one a polysaccharide of glucose, the second one a protein with mostly a certain sequence of amino acids. Thus, the IR spectra are different, too. By looking up the characteristic bands in textbooks [e.g. 8] even more information is gathered. With just a basic knowledge of how IR spectroscopy works, this method can be employed by students to compare spectra of given samples of fabric with spectra of their own clothing. A good example is clothing bought on vacations at a local outdoor market, which sometimes is made of another fabric than stated on the label.
For this experimental setup, students need basic knowledge of organic chemistry and natural and man-made polymers. The need for an IR spectrometer limits the use of this inquiry-based learning experiment to universities. Schools cooperating with universities could carry out this experiment with their higher grades at university laboratories.

4. Conclusion and outlook

These two examples of contributions to the field of inquiry-based learning can improve teaching at universities for all students in the field of chemistry. Stink bombs can be investigated at schools as well. Students should get more involved in the related topic and therefore more engaged with chemistry. More inquiry-based learning experiments still have to be developed and will be available in the near future.

By linking students' tasks to everyday materials, a better learning outcome could possibly obtained and is the topic of further research to be carried out.

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