FOPDA – Chemistry students perform like scientists

Summary:

We show in-service teacher and pre-service teacher one possibility to teach chemistry and especially scientific reasoning by a series of problem solving steps in their lessons. Under the direction of the Chemistry Education at the Humboldt-University teaching and learning materials for chemistry lessons (e.g. lesson plans, experiments, student workbooks, role plays) are designed according to the following FOPDA-framework.

Scientific Inquiry in chemistry lessons

- **F**ind question
- **O**rganise information
- **P**lan solution
- **D**o experiment/ carry out plan
- **A**nalyse solution

In order to this we created a framework which can be used as planning instrument for teacher promoting IBSE but also as helpful learning scheme for pupils. Moreover, materials according to transfer-facilitating factors are developed.

Aims:

The aims are multifaceted: It provides an opportunity for students to encounter scientific phenomena in different contexts and improve their inquiry skills. However, the main aim is to get teacher and pre-service teacher talking and thinking about teaching chemistry in constructive way. Therefore we present the FOPDA-scheme as one possible framework taking IBSE into chemistry lessons.

Student activities:

Students should gain specific knowledge regarding key questions of chemistry and basic techniques herein. They should carry out authentic experiments on their own, available at school due to resource as well as time limitations.

Pre-service teacher education:

Pre-service teachers should develop pedagogical content knowledge (PCK; Shulman, 1986) regarding teaching salts, acids and bases, alkanes, IBSE skills and problem solving competencies. As one part of PCK, they should be able to prepare and to carry out experiments within these issues which they should implement later on as future teacher at school. Pre-service teachers should also increase their content knowledge as well as parts of pedagogical knowledge.

In-service teachers' professional development (PD):

In-service teachers should achieve a higher level of PD by participating on the student courses as learners, and, especially, on specific experiments with regard to hands-on teaching those chemistry issues at school. Following the "teacher as learner" paradigm of professional development participants are treated as active learners so that they can construct their own understandings and knowledge about IBSE by using some of the developed materials as an example for teaching and learning chemistry with IBSE methodologies. In addition, they are ask to develop own materials and ideas in teams.

Main activities:

Teacher professional development: day-long experimental courses and workshops with theoretical foundation.

Lessons of in-service teachers after FOPDA-workshops at HUB with regard to teaching and learning chemistry through IBSE

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Narrative:

Teachers attend a day-long theoretical based IBSE workshop at HUB and increase their knowledge about key issues in teaching chemistry inquiry-based, apply the basic techniques herein. In parallel, science education research has provided a consistent evaluation regarding instructional efficiency.
Teachers often report, that students are unsure how to tackle an investigation even do small methodic sub steps such as declaring variables or sketching a table of results. A possible reason for that might be that previous learning of problem solving steps or problem solving strategies does not transfer to a new problem task. In order to create teaching and learning environments, that allow transfer, conditions that facilitate transfer need taken into classes.
We show in-service teacher and pre-service teacher one possibility to teach chemistry and especially scientific reasoning by a series of problem solving steps in their lessons. Under the direction of the Chemistry Education at the Humboldt-University teaching and learning materials for chemistry lessons (e.g. lesson plans, experiments, student workbooks) are designed according to the following FOPDA-framework.
Scientific Inquiry in chemistry lessons

- Find question
- Organise information
- Plan solution
- Do experiment/ carry out plan
- Analyse solution

Under these headlines the FOPDA-scheme presents detailed questions to support own investigation, e.g. what do we know already, which variable has to be constant and unchanged in my experiment. The target groups are pre-service teachers (i.e., university students for chemistry education), and chemistry in-service teachers. The developed materials cover the curriculum of 9th and 10 the grade in the region Berlin/Brandenburg.

The FOPDA-scheme itself does not follow the 10 principles of Best Practices because it is only a possible framework or scheme to structure lessons, structure lesson planning and structure students investigations. According to promote IBSE we developed lessons including this FOPDA-scheme which in the whole follow all of this principles but of course a single lesson does not cover every criterion. Therefore we will only present some exemplary descriptions of the realization of these criteria in our Best Practice example.

Methods of learning/training :
Pre-service teachers: evidence-based PCK development; in-service teachers: evidence-based professional development.

End user:
Pre-service and in-service teachers for chemistry education at two different stratification levels: the Gymnasium as a "university-preparatory secondary school" (highest level; up to the 12th grade); and the Sekundarschule, where students may receive the "intermediate secondary school-leaving certificate" (intermediate level, up to the 10th grade).
The developed materials cover obligatory according to the curriculum topics of 9th and 10th grade chemistry lessons.

Involved actors:
Science education researchers

Location:
Outreach laboratory at the Humboldt-Universität zu Berlin and if preferred, we will also come directly into the schools

Languages available:
German

Evaluation parameters:
Paper-pencil tests:

- Pre-and Post test to measure the changes in the views on Scientific Inquiry and Nature of Science of teachers participating at the teacher training activities.
- The transfer tests "Interim", "Post" and "Follow-up" were designed to analyse the transfer of schema main steps and schema sub steps on non-chemistry topics.

Videos are taken in order to record and evaluate teaching and learning processes.

Duration:

1. Student modules:
2. pre-service teacher modules: term-long experimental courses
3. in-service teachers: day-long

Optimum number of participants:
6 to 15 teacher

Additional information or resources:
www.tiemann-education.de/

Teachers' Competencies

1	subject matter/content knowledge	x
2	nature of science	x
3	Multidisciplinary	
4	knowledge of contemporary science	x
5	variety of (especially student-centred) instructional strategies	x
6	lifelong learning	x
7	self-reflection	x
8	teaching/ learning processes within the domain	x
9	using laboratories, experiments, projects	x
10	common sense knowledge and learning difficulties	x
11	use of ICTs	
12	knowledge, planning and use of curricular materials	x
13	Information and Communication Technologies with Technological Pedagogical Content Knowledge	x

PATHWAY

Mapping best practices with main principles

1. Building interest in natural science phenomena and explanations:

Observed phenomena and developed materials are close to everyday life and experience. Through exploration, experimentation, observation, collection of data, development of hypotheses, through first hand involvement of students and teachers, the activity aims to raise interest in chemistry.

2. Building up informed citizens: Students understanding the nature of Science & Science in society:

Nature of science: Within some lessons, students and teachers are confronted with key concepts describing the nature of science, for instance, the concept of acids and bases: Acids taste sour and turn litmus paper red, whereas bases feel soapy and turn litmus paper blue. Chemists, however, are seldom satisfied with phenomenological definitions such as these. The questions they ask is, "What is it about a certain molecule that makes it an acid or a base?". For more than a century, chemists wrestled with different definitions and understandings of acids and base. These concepts/ideas and its specific limitations are part of those lessons.

Science in society: For instance within the lessons of acids and bases, students and teachers discuss the role of science in society. In this case, they discuss and value the importance in industrial questions as well as in student`s daily life, the potential risks e.g. for environment.

4. Understanding students' concepts and learning style about of science phenomena:

Teachers get different chances to understand students' concepts with regard to the subject being taught and to get information about students' learning style:

1. Teacher discuss the results of the conceptual change research and research according to understandings of nature of science and scientific inquiry (always with regard to the specific chemistry issues) of student`s concepts.
2. During the workshops teachers are confronted with the current concepts of their colleagues and with different learning styles of the work group members, too.

5. Relevance of the content to daily life of students:

Is ponited out in some of the lessons. For instance questions students can work on during the lessons of "salts" are about cooking time of spaghetti with salt and without salt the water.

6. Understanding science as a process not as stable facts. Using up to date information of science and education:

Student`s work actively on scientific phenomena and questions using elements of the scientific knowledge acquisition process (e.g. raising questions, forming hypothesis, identifying variables …) integrating historical and recent views and attitudes on science.

7. Activities for gaining knowledge, not for entertainment, nor for simple imitating of results:

Both students and teachers gain scientific knowledge; teachers gain pedagogical content knowledge, but also content knowledge and pedagogical knowledge. Within the workshop, they do and plan students' experiments embedded in a framework of minds-on-hands-on units. Each unit consists of a theoretical minds-on phase as well as an associated experimental hands-on phase where participants cooperatively perform one experiment within a 3-4 person work group. Within the theoretical minds-on phases, the theoretical background of each experiment is explained. The teacher should learn to encourage the students to ask questions, to suggest experimental procedures and to hypothesize about the expected experimental results. Before the first minds-on-hands-on unit, the lessons include initial pre-lab phase activities so that the teacher introduces the students to the work area. The students learn to properly handle any equipment previously unknown to them. Within this final phase / interpretation phases of the lessons, the teacher and students discuss the actual results. Students compare the results with their previously formulated hypotheses and verify or reject their hypotheses. All experiments included in the lessons are authentic. The tutor role during the workshops provides the chance to counter against the self-experienced difficulties during the hands-on phases. Finally, the teacher role allows to include those experiences into own instructional strategy.

8. Doing science: experimenting, analyzing, interpreting, redefining explanations:

Both the students and teachers can use the FOPDA-framework in order to do science, including experimenting, analyzing, interpreting, and redefining explanations.

- The students attend experimental lessons using the framework to realize own investigations.
- The teachers do science both in the role of the school student the workshops and in the role of the tutor during the workshops and as a teacher later on.

9. Assessment: formative ~ of students' learning and the summative ~ of their progress:

- test to measure student`s pre knowledge and test to measure the cognitive abilities
- pre-and post-paper-pencil test to measure the changes in the views on Scientific Inquiry and Nature of Science of teachers participating at the teacher training activities.
- transfer tests "Interim", "Post" and "Follow-up" were designed to analyse the transfer of schema main steps and schema sub steps on non-chemistry topics.
- videos are taken in order to record and evaluate teaching and learning processes.

10. Cooperation among teachers and with experts:

The FOPDA-workshops bring together teachers from different schools in the area of Berlin. Due to complexity of some new experimental approaches, cooperation between the teachers may arise. Independently, they come in contact with science education researchers at HUB, and, content-dependently, with HUB experts in different fields of chemistry research.