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Teach Chemistry Forward
an Innovative Course Concept for Universities and Schools

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Abstract

The lack of qualified specialists and STEM teachers poses a big challenge to both the industry and the educational systems. In several countries (Belgium, France, Germany, UK …) recent studies show a further decrease in the number of graduates in these disciplines, which will be insufficient to meet the demand. Chemistry is particularly affected [1] - despite the good working conditions (high salary, future reliability), more than 70 % of all pupils cannot imagine to take up a profession in this field of activity [2]. This results mainly from the fact that students perceive chemistry as 'hard' or 'abstract' and only rarely have a clear concept of chemistry studies, professional fields and activities [3,4].

In this contribution, we present a course concept for universities designed to address these challenges. The basic idea consists of the self-responsible preparation of a selected subject matter in chemistry or biology for school education. While chemistry, biology and didactics professors provide infrastructure and assistance if needed, STEM students develop teaching materials and experiments independently in tandems. Subsequent to an internal piloting, they pass on their original learning content as a teacher to pupils in our partner school network.

*This project offers several positive outcomes. With the help of selected examples we want to illustrate that (1) **pupils** gain insights into current scientific research topics and STEM degree programs, guided by highly motivated students, (2) **STEM students** acquire basic didactic knowledge during transfer from input to output and further gain experience in explaining their expertise to nonprofessionals, which represents a valuable key qualification for their future work life.*

Keywords: Cooperation School-University, Didactic Reconstruction, Science Education

1. Challenges: Learning Science Subjects at School and University

In the course of the Bologna reform to a Bachelor's/ Master's system, the number of students at universities is constantly increasing. However, this trend does not apply to STEM subjects (including chemistry) where the number of students is stagnating. One of the main reasons for this is a very **negative image of chemistry**, which is often perceived at school as 'hard', 'mathematical' and 'abstract'. As a result, more than **70%** of the pupils cannot imagine studying a STEM subject or taking up such a profession, according to current studies [3,4].

This problem continues in university STEM degree courses. In science courses, knowledge is typically imparted through lectures or seminars. Within these teacher-centered learning formats, only a smaller fraction of the time is spent on active learning and students can thus only retain **small amounts** of the presented knowledge [5,6]. Therefore, it is a well-known problem that students often acquire knowledge in a short period of time, reproduce it for the final exam and forget much of it in the long run.

In this article, we present a comprehensive course concept for university and school that addresses both challenges and can benefit students and pupils alike.

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2. Course Concept

In 2012, the course concept **Teach It Forward** was developed at the Technical University of Braunschweig [7]. The basic idea consists of the development and preparation of a school lesson by students in order to teach it forward to high school pupils. The main element of this concept is the **change of perspective** when students become teachers themselves. Rather than (passively) visiting lectures, students of biology and biotechnology acquire selected contents on their own initiative in learning groups. By teaching these contents, they can not only learn them more efficiently, but also transfer this knowledge to different contexts [7]. Lastly, the self-guided preparation encourages team-oriented, structured work.

This award-winning course concept was transferred from biology to chemistry in 2017. For the development of **Teach Chemistry Forward**, various adaptations to the specific characteristics of chemistry were necessary, especially with regard to the safety precautions during the chemical experiments. Beyond the adaptation, the seminar concept was also extended in terms of content. Given the above-mentioned perception of chemistry, special emphasis was placed on the **didactic reconstruction** of the scientific content. By including basic knowledge of chemistry didactics, the authors aimed to significantly improve the quality of the teaching materials developed.

2.1 Course Structure

Teach Chemistry Forward's course concept consists of six sessions, which are divided into the sections **Preparation**, **Planning** and **Presentation**. The aim is to create an independent teaching lesson for one subject area, which will lastly be taught in a school class.

- In the **first section**, students form learning groups and then start to search for a suitable topic. The aim is to select a research area that can ideally be linked to the chemistry curriculum, but goes beyond the typical school content. University lectures, seminars, research projects or bachelor/ master thesis can provide a variety of possible ideas.
- The **second section** of the seminar focuses on lesson planning. For this purpose, the lecturers present basic knowledge and concepts of chemistry didactics in short lectures. The contents include (among others) safe experimenting, learners' pre-concepts/misconceptions in chemistry, teaching methods as well as time management. On this basis, students start to construct their lessons during the following weeks. In parallel to structuring the content, they develop and test accompanying key experiments.
- Students present their intermediate results regularly throughout the seminar in the plenary session and receive feedback from the other participants and the lecturers. Finally, a rehearsal and discussion of the entire lesson will take place in the **third section** of the presentation before the school visit.

The resulting lesson plan is taught in the presence of the lecturers and the subject teachers in class. Afterwards, they provide feedback to the students and thus offer an opportunity to reflect on and revise their lesson.

2.2 Aims and Objectives of Teach Chemistry Forward

A special feature of the presented seminar is its project-oriented character and a high level of learner activity. Students choose their topics independently and according to their own interests from the variety of current research fields. The majority of the development also takes place on one's own initiative. Lecturers, on the other hand, take up an advisory position - as learning guides they offer the necessary infrastructure, organization and provide didactic-methodological impulses and support, if needed. Through their participation in Teach Chemistry Forward, students can benefit from this learning concept in several ways:

- By designing a lesson plan, the students get a **deeper insight** into their research topic. By teaching the learning material themselves, students can retain their gained knowledge longer.
- Within the framework of the seminar, students acquire **basic didactic knowledge** for the teaching of scientific content and improve their **professional communication skills**. This represents an important key qualification for professional practice.
- The preparation in small groups strengthens their ability to **work in a team**.
- The teaching of the **self-learned subject** matter in front of a school class trains the students **presentation skills**.

Pupils also benefit from the participation by gaining insight in current chemistry topics by highly motivated students. By establishing a link between chemical research and current societal problems, the **importance of chemistry** can be emphasized in a simple and illustrative way. At the same time, students can share their impressions of studying chemistry. This gives students the opportunity to obtain **first-hand-information** on the chemistry study programs, which may enhance or facilitate their choice of career and subject.

3. Implementation, Experiences and Outlook

The underlying concept of Teach It Forward has already been implemented several times in teaching practice. In order to make this possible, a **regional network of partner schools** was built up beforehand in order to coordinate school attendance and to adapt the chosen topics (if possible) in terms of content to the curriculum. The seminar management carries out the allocation to the schools, the arrangements regarding date, equipment and learning group are carried out together with the students.

In the framework of Teach It Forward, a **wide range of projects** on current research topics in biology has been carried out. In a first run of Teach Chemistry Forward, these topics are currently expanded by chemical projects. Selected examples are

- **Genetics:** DNA analysis, genetic engineering, methods of green biotechnology, CRISPR/Cas
- **Microbiology:** Evolution, bacteria in biotechnology, microorganisms and enzymes
- **Biomedicine:** stem cell research, immune defence and dysfunction, insulin, drugs - why do we become addicted
- **Neurobiology:** Brainbow with fluorescence microscopy, learning and memory functions, human nerve conduction, neuronal interaction
- **Analytical chemistry:** structure determination by X-ray diffraction of crystals, detection reactions with fluorescent dyes
- **Nanotechnology:** DNA-Origami, molecular rulers and machines, from light microscopy to fluorescence microscopy

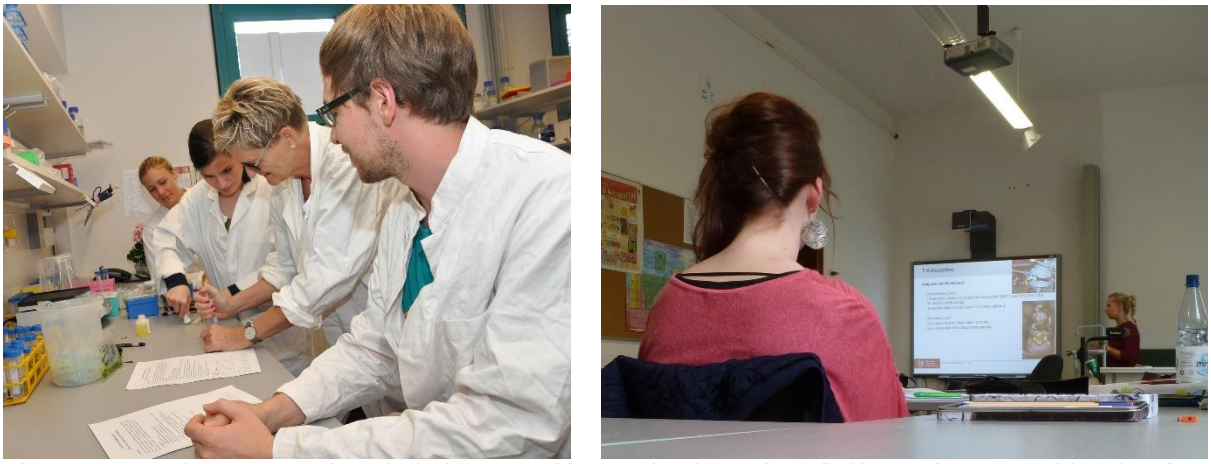

Figure 1: Students preparing their lesson with a school teacher (left); students teaching in class (right).

In the evaluations carried out until now, this project has been **well rated** by the students and teachers involved. More than **90%** of the participants state that (1) they consider the acquired competences to be **important for their later professional life**, (2) they are able to present complicated facts in a clear way due to attending the course and (3) the seminar has **strengthened their interest in the chosen topics**. Some students have even participated in this module several times, although it is only credited once in their studies. In the context of the current test run, these questions will be investigated for Teach Chemistry Forward by means of qualitative research methods. First experiences from the current seminar confirm these impressions.

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