Development of Blended Learning Units for an Introductory Course in Chemistry

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Abstract

University dropout is caused by a variety of reasons: financial problems of students, sickness, mismatch between the study program and the students' interests of study etc. However, the most common reasons for student university dropout in science studies are their obvious deficiencies in the respective conceptual knowledge of science. To counteract this, introductory courses are offered which prepare prospective students for their first term by teaching basic science concepts.

At the university of Göttingen, we are currently designing an introductory course for chemistry students in major and minor programs. In a preliminary study, we determined students' prior knowledge and chemical misconceptions in order to adapt the contents and methods of the course to the needs of our students. The consideration of these needs resulted in the development of blended learning units on basic chemistry topics like atomic structure, chemical bonding, chemical reactions and stoichiometry as well as basics in organic chemistry and mathematics.

In this contribution, we will describe and discuss selected aspects for the design of these blended learning units. Within this discussion, we will focus on the roles of contextualization of the chemical contents, multimedia learning in chemistry and determining and treating misconceptions in chemistry.

1. Introduction

Introductory courses (or synonymously preparatory/preliminary courses) in chemistry play an important role in higher level chemistry education. These courses provide good opportunities to reduce dropout rates of chemistry-related study programs by teaching basic chemistry as well as further relevant subjects like basic math or physics prior to commencing a study [1]. Dropouts in science courses are often caused by students' failing of tests in their first terms and their lack of conceptual knowledge [2]. With respect to this, preparing students for their first term in introductory courses has been proven effective in several studies [3,4].

Figure 1 shows a model with relevant didactical aspects extracted from recent literature that have been considered in the development of our introductory course. First of all, it is important to explore which requirements our students have (*addresses of teaching*). Among these are their content-specific prior knowledge, their motivation, their self-efficacy and their learning strategies which have all been considered relevant in educational psychology and chemistry didactics research [5,6]. These factors determine what should be taught (*the content of teaching*), how it should be taught (*the methods of teaching*) and which distribution between Face-to-Face and E-Learning seems helpful (*the model of teaching*). These factors become relevant in the *organization of teaching*: who teaches the course, in which room is it taught, when does the course take place and who is financing it etc. Finally, the course concept needs to be evaluated and adapted appropriately (*evaluation of teaching*) [7].

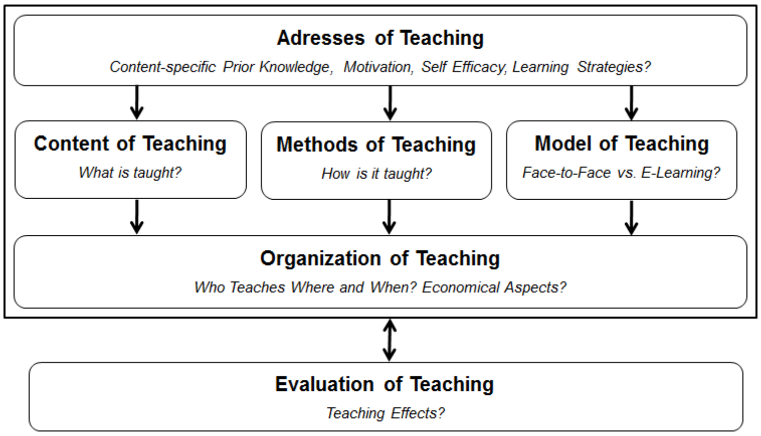

Figure 1. Hierarchical model of relevant aspects for the development of an introductory course.

Based on these considerations at the Georg-August-University Göttingen, we are developing an introductory course in chemistry termed as 'Chemtroduction'. We have decided to offer this course as a Blended-Learning Course due to the mutual benefits of combined E-Learning and Face-to-Face Learning [8]. The course will be suited for chemistry students in major and minor programs. A study on the prior knowledge and the misconceptions of students in their first term, several discussions with the teaching staff at our university and a consideration of school curricula suggests the development of teaching units on the topics atomic structure, chemical bonding, chemical reactions, stoichiometry and basics in organic chemistry. The units will be designed as multimedia and interactive learning units using the Learning-Management-System ILIAS [9].
Within this paper, we will describe and discuss the structure and the design principles for the learning units. Finally, we will show further research questions on introductory courses in chemistry that will be examined in our project.

2. Description of the Learning Units' Structure

First of all, each learning unit is divided into sub-units on specific parts of the topic. To give an example, the unit on chemical reactions has sub-units on the definition of a chemical reaction, physical changes, kinetics and chemical equilibrium, thermodynamics, redox reactions and acid-base reactions. Secondly, each sub-unit consists of four sections: *Pretest, Introduction, Learning Material and Posttest.* Figure 2 shows the structure of a sub-unit.

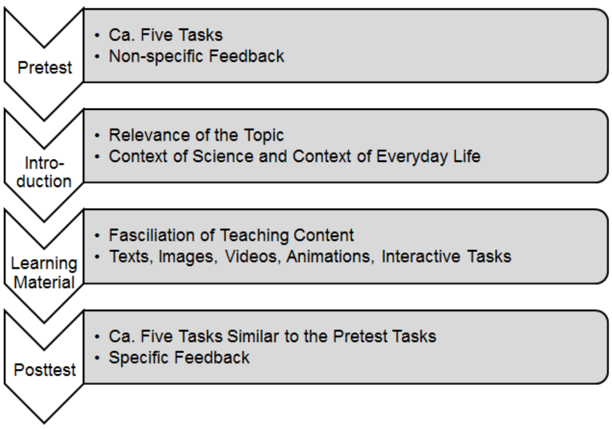

Figure 2. Structure and elements of a sub-unit within the introductory course.

In the *Pretest Section*, students will be given a questionnaire on the topic that will be taught in the following section in order to activate their prior knowledge and to check if they have common misconceptions on the topic [10]. With respect to acid-base reactions *e.g.*, it has been shown that students often consider acids as dangerous but not alkaline solutions since they are used in the washing machines [11]. After the Pretest, students are given an *Introduction* into the topic where the relevance of the topic in the context of science and everyday life is displayed. This introduction has the function of motivating the students and contextualizing the concepts that are taught in the following section. As a next step, the *Learning Material* is presented to the students consisting of texts, pictures, animations, videos and interactive learning tasks. Finally, the students are invited to take a *Posttest* which has the function of giving them a detailed feedback on their state of learning and referring them to certain parts and tasks of the unit which might still be a problem for them.
Finally, after each learning unit there will be a Face-to-Face learning session. In this session, students will work on exercises and problem-based tasks according to their state of learning. Since misconceptions in chemistry have been proven to be very persistent, students that still hold certain misconceptions will be given additional group exercises that challenge their misconceptions [10]. For example, if they have misconceptions about chemical equilibrium, they are assigned to the task of predicting the amount of water that will be produced when 1 mol of ethanol and 1 mol of acetic acid react to ethyl acetate and water. Then, they will conduct the experiment to check if their predictions were correct.

3. Description and Discussion of the Learning Units' Design Principles

After having described the structure of our learning units, we will now describe and discuss their design principles: the Principles of Multimedia Design, the Principles of Comprehensive Texts, the Principle of Contextualization and the Principle of Example-Based Learning.
The Principles of Multimedia Design have been developed by Mayer and his colleagues on a profound basis of empirical studies [12]. Apart from others, Mayer stated the following principles:

(1) People learn better if texts and pictures are presented instead of texts alone (*Multimedia Principle*),
(2) but only if a close interrelation between texts and pictures instead of an arbitrary connection is given (*Coherence Principle*).
(3) Furthermore, people learn better if a video or an animation is presented with spoken rather than written language (*Modality Principle*),
(4) people learn better when sounds are presented simultaneously in animations and videos and labels are included in the images rather than near them (*Spatial and Temporal Contiguity Principle*) and
(5) adding texts to a combination of animations or videos and sounds is not helpful for learners (*Redundancy Principle*).

According to principles (1) and (2), we will include many explaining and demonstrating images and diagrams in our learning units but limit the images that are simply illustrating, *e.g.* pictures of famous chemists. However, providing comics and other humorous images which have a rather loose connection to the text and therefore disrespect principle (2) is likely to motivate students and creates a positive learning atmosphere; therefore, those images will be carefully implemented in the learning units [13].The other principles are respected accordingly.
To design our texts, the Principles of Comprehensive Texts which were developed by the German psychologists Langer, Schulz von Thun and Tausch are considered. These principles advice to write short sentences, structure the texts in subsections, use familiar words, use verbs instead of nominalizations and personalize the writing by addressing the text directly to the reader [14]. Of course, using familiar words does not mean that scientific terms are forbidden, but these are well

defined before they are used in the text. Apart from that, we keep in mind that students will have to master challenging texts during their studies, which is why we give them additional reading tasks in the Face-to-Face learning sessions.

The Principle of Contextualization is respected by providing meaningful contexts to students in the introductions and also in the units. This includes both highlighting the connection of the taught concepts to related scientific concepts and showing everyday life applications. Research of Bennett, Hogarth & Lubben has shown that these kinds of contexts in teaching chemistry are motivating for students [15].

Finally, the Principle of Example-Based Learning suggests giving our students worked examples on abstract rules and concepts before solving tasks on their own. This procedure has been proven superior to working on tasks without analyzing examples first [16]. Besides, ILIAS provides different types of tasks with given response options, *e.g.* single-choice tasks, multiple-choice tasks, numeric tasks or image maps [9]. An example of the latter is given in figure 3. In this task, the student is asked to click on the cathode, with the circled areas as response options.

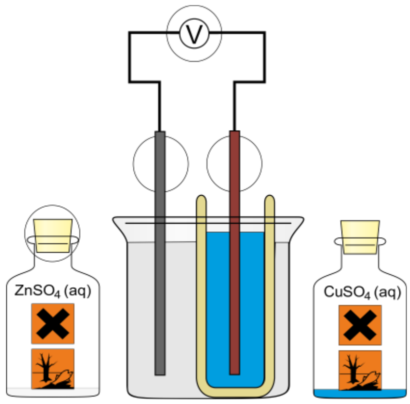

Figure 3. Example for an image map task.

Tasks with open response options and problem-based tasks are provided in the Face-to-Face-learning sessions.

4. Summary and Outlook

To sum up, our learning units on atomic structure, chemical bonding, chemical reactions, stoichiometry and basics in organic chemistry each consist of sub-units with a pretest, an introduction, a multimedia-unit and a posttest. These are designed using the principles of comprehensive texts, contextualization and multimedia learning. Along with these structure and design principles, relevant results of research in educational psychology and chemistry didactics are considered.

Apart from these theoretical learning units, there will also be an introductive lab phase in which students will conduct both qualitative and quantitative lab experiments and get used to the most common lab equipment, *e.g.* gas burners, heating plates etc. Research has shown that it might also be helpful to support the lab phase with ILIAS modules which prepare students for their own lab experience and help them to evaluate the experiments [17]. Therefore, respective modules will also be implemented. Within our project of developing an introductory course in chemistry for the Georg-August-University Göttingen, two of the research questions that will be examined are the following:

(1) Can the knowledge gaps of our students be closed and common misconceptions be disregarded? Since this is the main goal of our course, a pretest-posttest control group design will provide an answer to these questions.

(2) Do students develop realistic self-efficacy? Since a realistic view of ones' own abilities and deficiencies is a basis for self-regulated learning, the self-efficacy of our students will be tracked by several questionnaires [4].
In this way, our project will contribute to the research in chemistry teaching in the transition between secondary school and higher education.

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