Connecting Exercises and Video Tutorials to Support Teaching/Learning Processes in University Chemistry Education

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Abstract

In this contribution we will present a project for chemistry students in their freshmen years supporting teaching/learning processes, in which solutions for typical exercises are being presented in the form of complementary video tutorials. The main goal of these so-called sets is the revision of specific subject matter in order to close possible knowledge gaps. Each video contains step-by-step explanations and clarifications, appealing to a broad spectrum of students with varying degrees of prior knowledge. The provided explanations are based on distinct learning principles such as the learning from textbook examples, the interlinking of representational levels in terms of Connected Chemistry, as well as learning by means of graduated teaching aids. Depending on the students' prior knowledge, the sets may have different purposes in the students' learning processes such as: (a) the revision of fundamental knowledge, (b) the verification of results, (c) the introduction and reflection of alternate approaches, (d) supporting the acquisition and consolidation of self-diagnostic skills, and hence (e) supporting the enhancement of self-regulated learning competencies. Additionally, these sets offer various opportunities for the individualization of teaching/learning processes, with the goal of counteracting the students' heterogeneous prerequisites. We will therefore present several options for the implementation of these sets into educational settings, e.g. using concepts such as the inverted classroom method.

1. Introduction

Task-based video tutorials lead to optimized teaching and learning processes in the fundamental chemistry education in universities [1,2]. If these are functionally incorporated into the overall context of learning processes and if the presented information are elaborately processed by the students, a deeper understanding of subject-specific fundamental knowledge can be achieved [3].

The main advantage of video tutorials over other learning techniques is the connection of both visual and auditory elements. Hence, difficult concepts and interrelations can be visualized more easily, since crucial information can be incorporated over several sensory channels [3]. The comprehension of chemical interrelations can be further improved by applying the representation levels by *Johnstone* [4]. Studies distinctly show that learners develop a more profound understanding of concepts, if phenomena are at first being explained at a macroscopic level before being presented at a submicroscopic and representative level. This allows a reorganization of inaccurate pre-concepts as well as studying distinct concepts in a more profound manner [5-7].

2. Description of the Sets

The sets are consisting of video tutorials with tasks and explanations on specifically chosen topics on general as well as inorganic chemistry, aiming to individually closing knowledge gaps in subject-related areas of competency. The crucial understanding of chemical interrelations is the requirement for recognizing, explaining and understanding new contents and phenomena.
Regarding the different topics, the students work on classic qualitative and quantitative tasks varying in their level of difficulty. The process of studying and repeating happens in a cumulative way, since the tasks are strongly tied to the students' previous knowledge. A connection to the students' experiences and everyday lives further facilitate the acquisition of contents [8]. Thus, students are generally more motivated to solve even complex tasks, resulting in more positive learning experiences and positively correlating with a feeling of contentment in the students, as well as an enhanced

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intrinsic motivation [1]. If students encounter problems of comprehension while working on the different tasks they are being encouraged to turn to said video tutorials for further explanations. The development and design of the video tutorials follow the Cognitive Theory of Multimedia Learning by *Mayer* [9]. The different media elements are being didactically combined in order to maximally activate the learners as well as to enable them to elaborately and sustainably process the information.
Within the videos, step-by-step explanations are being used to explain the different tasks and their underlying concepts, enabling students with varying amounts of prior knowledge to improve their conceptual understanding. Various studies show that students can solve problems most effectively, when initially a concise experiment is being presented [5-7]. Experiments play an important role in gaining scientific knowledge such as (a) the visualization of phenomena and therefore (b) a simplified access to complex topics, (c) the promotion of enthusiasm and motivation while working on scientific questions, (d) the reinforcement and consolidation of the students' competencies as well as (e) the examination and assessment of the own competencies [10].
Figure 1 shows segments of a video tutorial on the topic of acids and bases. Based on the chosen experiments, students can observe various phenomena on a macroscopic level, supported by explanations on the submicroscopic as well as the representative level. The interlinking of representational levels happens in the sense of the so-called Connected Chemistry, enabling students to acquire a basic conceptual understanding, which is the main requirement to achieving a more profound understanding of the different chemical concepts [11]. The observations that can be made during the experiment are being described step-by-step and are subsequently being explained on a submicroscopic and representative level. Since most students often have problems with connecting the macroscopic to the submicroscopic level, models highlighting the interactions on a molecular level are being integrated into the videos, descriptively supporting the gaining of knowledge [5].

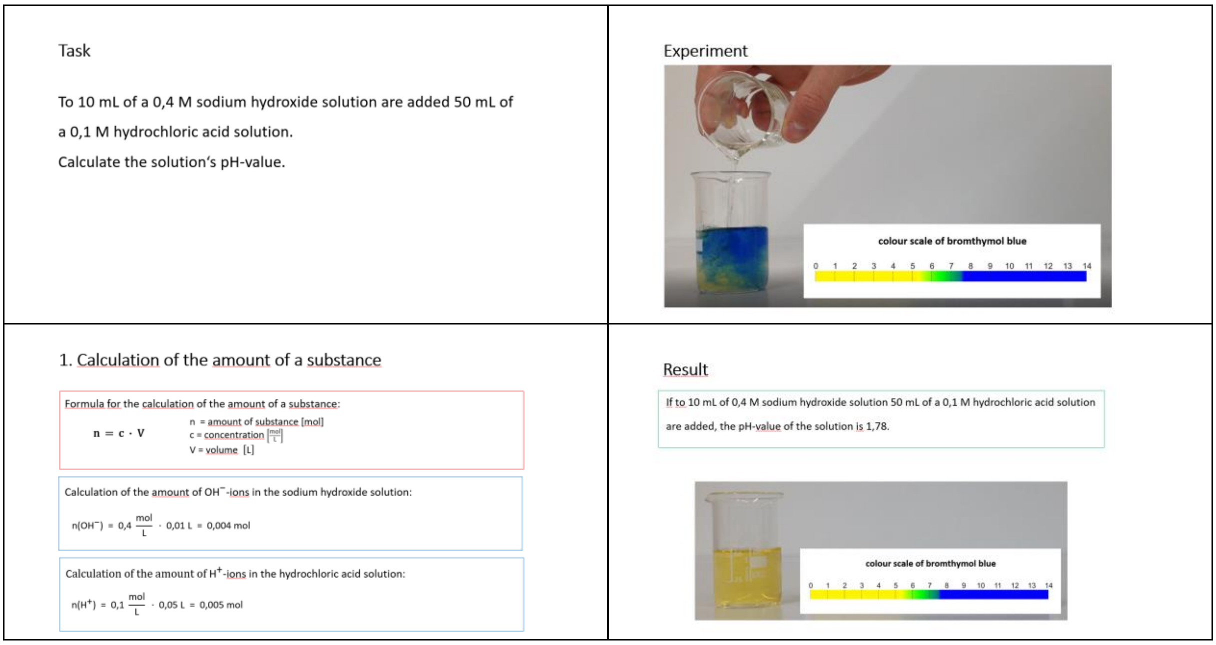

Fig. 1: Sequences of a video tutorial about acid-base-chemistry.

On the basis of theses qualitative explanations, the tasks are subsequently being illustrated in a quantitative sense. The solutions of the calculations are being explained and justified in multiple stages using step-by-step explanations, offering students with differing predispositions several learning opportunities. This method of learning from classical textbook examples, versus learning from conventional problem-solving tasks, is especially learning-effective for freshmen students, as several studies have shown [12].
The step-by-step solutions can later be transferred to similar questions and tasks. Especially students with low subject-specific competencies profit from this method, since they oftentimes struggle immensely with autonomously working out the solutions to such exercises. Due to the in-depth consideration with the textbook examples, the students' prior knowledge is being activated.

Subsequently they have to continually question their already existing knowledge and relate it to the recently gained information, consequently building up a new amount of knowledge [13].
Students whose subject-specific competencies are more pronounced have the opportunity to use the videos as a confirmation tool after they autonomously solve the different tasks. Students with a mediocre amount of competencies mostly use such video tutorials to acquire knowledge using the exemplary explanations. They use the information given in the videos to paraphrase the contents and to generate a basic understanding of the given example. However, the understanding of the given interrelations does not jet suffice to effectively solve following exercises on their own.
Hence, in order to acquire problem-solving competencies, it is necessary to gain content-based competencies through further tasks and examples in order to interrelate different knowledge elements and to being able to use them in various situations [13]. Due to the precise explanations in the video tutorials, students feel less often overexerted and therefore more competent, are learning more actively and therefore more effectively, which leads to greater success rates and at the same time enhances their intrinsic motivation [1].

3. Implementation of the Sets

The task catalog and the video tutorials can be variably applied to acquire, revise or deepen theoretical basics. The sets can be used by prospective students, for instance, to prepare for chemistry study programs. Studies show that prospective students using tutorial instructions are more motivated when confronted with complex activities and questions, are more autonomous learners and later achieve better grades in their first exams compared to their fellow students.
The sets can furthermore be used as a modern approach to learning during the course of study, as part of the inverted classroom concept. Within this concept, students work autonomously on the basic contents and theories of a topic during their spare time, using different materials and tasks, e.g. in the form of video tutorials. In class, students then have the opportunity to ask questions and to deepen their knowledge working on further exercises [14].
The crucial advantage of this learning method is that students, depending on their individual requirements, can decide how much time they spend with a certain task. Thus, heterogeneous predispositions can be compensated more expediently compared to other, more classical teaching/learning methods. If necessary, the video tutorials can be paused or replayed, in order to fully comprehend the given explanations or to look up additional information in textbooks.
Problems may arise, if only few or none of the students come prepared to the sessions in class, since the heterogeneous predispositions will then be more pronounced. Graded tests at the beginning of each class covering essential information from the tutorials could help to counteract this problem and might help to extrinsically motivate the students to prepare for class. An additional advantage could be that students might reflect on their learning habits, leading to conclusions for the adjustment of such habits.
Moreover, this method supports self-organized learning as an interdisciplinary learning goal. The students gradually mature towards a responsible and self-regulated learning, encouraging them to systematically gain learning competencies as well as self-sufficiency [15].

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