Chemistry for Medical Students: How to Foster Students' Engagement?

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Abstract

Teaching chemistry as a minor subject at universities is often cumbersome as the students' engagement is generally low due to low acceptance of the discipline combined with high barriers such as a formalized language. Here we present an approach to improve medical students' engagement and participation in chemistry classes, which uses digital strategies based on the ILIAS open source e-Learning platform to improve teaching and learning within lectures, seminars and lab courses. It specifically addresses problems in lectures arising from the heterogeneity of preknowledge within a cohort. Before each lecture students are given an electronic pre-test to check on prior knowledge regarding the lecture topics and specific misconceptions about these topics. The results of these tests are evaluated, and each lecture is designed specifically to address these misconceptions and even out differences in prior knowledge among all students. Within the lecture several concept checks using clicker systems are included to test if the misconceptions were resolved during the lecture. These clicker-system based tests allow for breaks of the frontal teaching phase within the lecture and encourages students to discuss the topics with each other and the lecturer. Afterwards, the test prior to the following lecture is designed to check again for the already identified misconceptions as well as new misconceptions about the upcoming topics.

After each test, the students' gain access to a short instructional unit which includes very fundamental content of the upcoming lecture. By independently studying the instructional unit in ILIAS familiarity with the "language of chemistry" is generated leading to a lower barrier and compensation for the large heterogeneity in preknowledge. Within these units' text, images and especially animations are used to visualize e.g. the lewis concept and the connection of different chemical notations.

In addition to the test for misconceptions, exercises for the self-assessment of the students are provided for each topic, including best practice examples and tutorial videos for several rather complicated exercises.

Keywords: *digitalisation, just in time teaching, concept checks, animations.*

1. Introduction

It is well known that representations in Chemistry are one source for students' conceptual errors [1]. In addition, the representations are often an obstacle itself and lead to students trying to understand a kind of representatonal chemistry language instead of the discussed topics intended by the lecturer. The problem is quite prominent when chemistry is taught as a minor subject in german universities, as most lectures are not designed with problems of "reading chemistry" in mind and lecturer are often not well enough trained in methods and didactics.[2] This is one of the reasons leading to very negative perception of basic STEM courses.[3] It is often assumed, that the students dislike the difficult to understand scientific disciplines which are not a direct part of their major subject, but studies showed that it is not the difficulty, but rather missing methodology in teaching and missing links to the major subjects which lead to a very negative perception.

It was already implied, that a change in methodology, especially using new media and digitalisation in combination with classical lecture formats allow to improve the acceptance of chemistry as a minor subject.[4], [5] Here I present a fully digital supported strategy for a 1st semester course chemistry for medical students, comprised of a lecture preceeding practical lab courses and seminars.

Prior to the changes in course design the lecture was comprised of a classical frontal lecture using powerpoint. Evaluation of this lecture showed that 7 of 10 students found chemistry to be the most complicated pre-clinical subject. 2014 we evaluated the drop out rate of the lecture and found that 76% (175) of the first year medical students participated in the first non-mandatory lecture whereas only 9.5% (25) attended the last lecture. Having these numbers in mind, it is obvious, that most students attended the succeeding seminars with little to no knowledge. Only roughly 30% of the students affirmed to have done independent studies to prepare for seminars and lab courses in chemistry.

Here I present a course design which addresses the great heterogeneity within a cohort, guides the students to independent studies, reduces the students preparational time and fosters the students' engagement.

2. Course Design

The basic idea is: Every student should be able to follow every lecture and lectures should address misconceptions of the students, giving a better preparation of the students for the upcoming seminars. Therefore, the measures to be developed needed to: 1. Allow students of every proficiency level to prepare for the lectures in a minimal amount of time, 2. Establish a double feedback mechanism, where students are allowed to do self-assessment and evaluate their progress where at the same time the lecturer gets feedback on the students' progress misconceptions. As students at the University Göttingen are generally familiar with eLearning platform ILIAS, it was used to establish the digital support for the lecture

In a first step the idea was to design each lecture according to the predominant misconceptions and problems in understanding chemistry within the cohort. Therefore, students were asked to voluntary answer very short (3 to 8 questions) tests prior to each lecture.

2.1 Cohort specific lectures

To allow all students to follow and participate in the lecture, the information in the tests prior to the lectures was used to redesign the lecture according to the problems identified but also allowed to identify concepts which didn't need further explanation (Fig. 1).

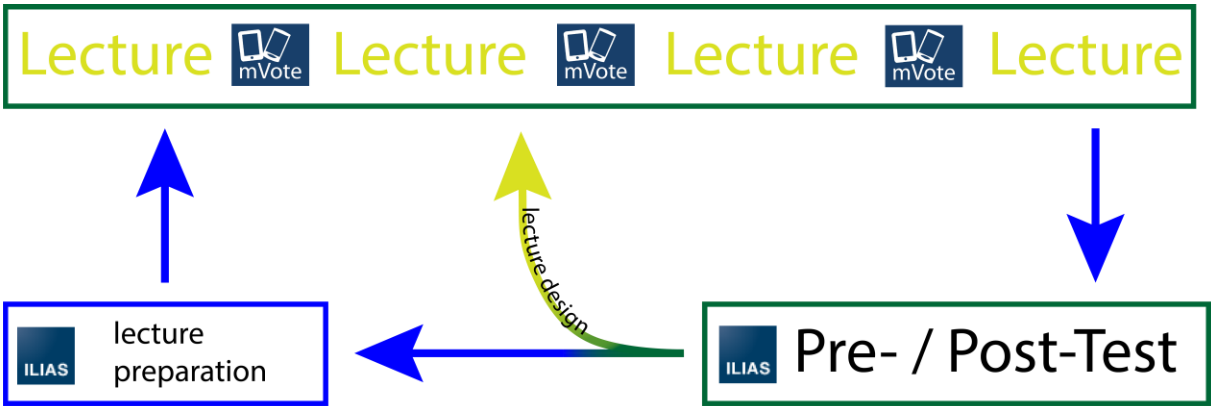

Figure 1. A cycle of Pre-Test - preparational eLaerning – lecture for the students shown in blue+green. Students' feedback is used by the lecturer to design each teaching unit (shown in yellow). Lectures are supported by concept checks done with mVote.

In addition students were able to assess their progress in chemistry based on the pre-/post-test results themselves. Examples for typical questions of the organic lecture part are given in figure 2.

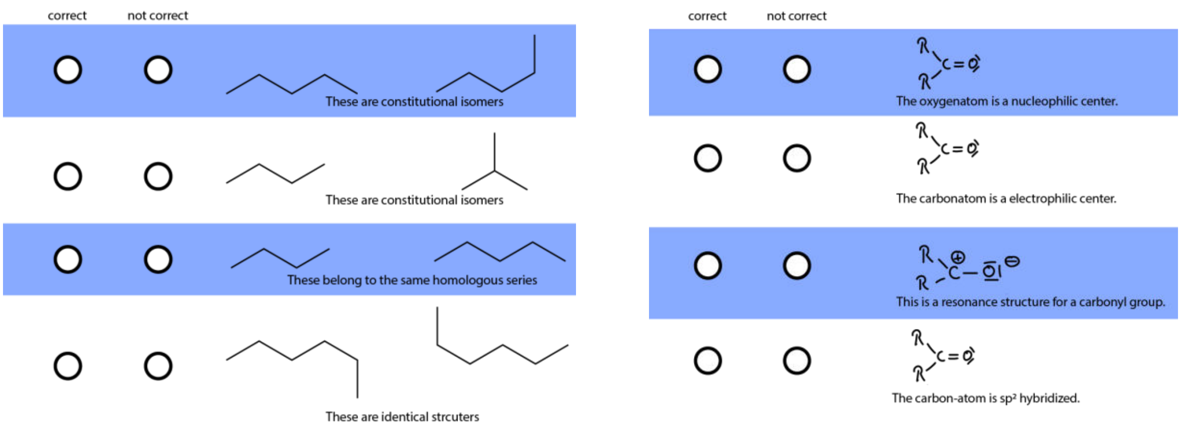

Figure 2 Two examples for typical T/F-questions used to check for the preknowledge of the students.

These questions address some very basic ideas of chemistry, visual representations and the ability to read and interpret them and was asked after these concepts were introduced in the previous lecture. 122 students answered the question, only 58% of the students were able to answer more than 2 of these statements correctly. Since lectures generally have a low level of redundancy in topics and the ability to read and interprete chemical structures is a key skill in understanding and learning chemistry, it must be assumed that only half of the students might be able to follow the upcoming lectures. Of course, the chemical syntax and representations are part of the curriculum, but looking at German universities the complexity of reading chemical representations is not discussed in great detail, in contrast to educational science dealing with chemistry in school curriculae.[6], [7] Furthermore, observations like this were made for every concept introduced within the lecture, e.g. in the case of identification of electrophilic/nucleophilic centres of reactions only 50% of 70 students were able to identify these correctly using compounds like carbonyls and amines. Very interestingly all major barriers are somehow related to reading and interpreting the chemical syntax. While 80% students were able to give the correct definition of nucleophiles and electrophiles only 50% could relate this to chemical structures in carbonyls.

2.2 Guided independent studies

To help the students in understanding chemical representations electronic learning modules in ILIAS were developed, which focused on the very basic principles necessary to follow the upcoming lecture. A key feature was using animations of chemical representations in combination with typical written explanations and images. Fig.3 shows a sequence of such an animation explaining mesomeric structures for benzene.

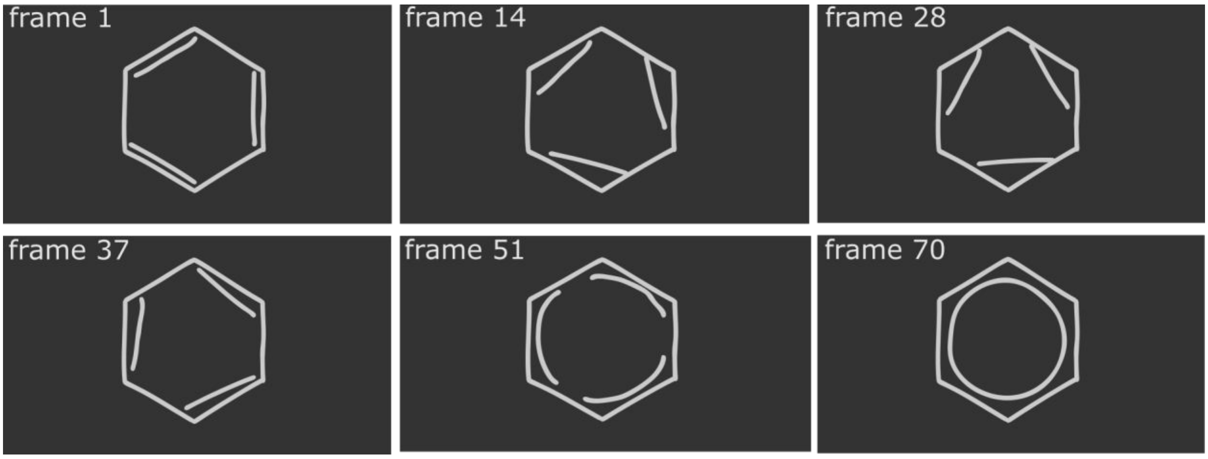

Figure 3 A Typical sequence used in an animation to explain mesomeric structures of benzene and the different representations. The movement of the π-electrons is explained by the structure of the π-orbitals in the aromatic system.

The eLearning modules for the preparation of the lectures were designed to be done in 20 minutes, and the pre-tests are mandatory to access the eLearning module. While more than 50% of the students carried out tests and preparations in the first lectures, this was reduced to 33% in the last lecture.
First evaluation of the eLearning module showed, that it seems to be most effective in reducing the barrier to approach the topic, leading to a kind of familiarity with the representations used in the lecture, shifting the students focus from reading the structures to using the structures. In addition, the visualized movement of bonds and electron pairs was described by most students as very descriptive.[4] Evaluation of the effectiveness of these animations is still to be done.

In addition, concept checks using the clicker system mVote, which utilizes students smartphones, were introduced within each lecture. Each lecture is designed in four parts of teaching using powerpoint and the black board, followed by a concept check (Fig. 1). These breaks in lecture helped the students to recover after a phase of high cognitive load and allowed the identification of misconceptions within the lecture. Furthermore, besides direct discussion with the lecturer, also discussions between students were fostered, leading to situations where students explained solutions to problems given in the concept checks.

2.4 The resulting effects

Derived from free-text evaluations of the lecture, the several possibilities of communication to the lecturer, direct and indirect, lead to a feeling of taken seriously, which greatly enhanced the students engagement. In combination with the easy to access preparational eLearning modules students were empowered in the ability to independently study chemistry. This feedback was partly or in total given in 78 of 152 evaluations. Furthermore, the amount of questions asked within the lecture increased greatly and students remarks by eMail to the lecturer about problems they have when learning raised from typically none to roughly 2 per lecture.
The drop out rate of the lecture reduced dramatically, while the first lectures were attended by over 200 students, which is more than 90% the last lecture was still attended by more than 100 students. These numbers are estimates based on the students taking part in the concept checks, we did not count the numbers. The resulting tests to pass the class, did not change in overall pass rate (76%) but the discrimination between students that passed and such that did not increased greatly.
The total amount of time to prepare the lecture tripled roughly for the lecturer, but instead of just slowing down the lecture topics could be intensified by reducing the barrier to access and understand the topics and focusing in students' needs.

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