International Conference NEW PERSPECTIVES in SCIENCE EDUCATION

Reimagining student laboratories: creating a digitalized chemistry lab

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Abstract

The potential to make students experts in their own learning is often allocated to the use of digital media in learning settings [1]*. At the Friedrich Schiller University of Jena, a chemical student laboratory is therefore being created, which will serve to test and research the use of digital media within a chemistry (lab) context. This digitalchemlab is a supplement to the already existing classical student laboratory. Digital media can be used to create an interesting and highly customised design of the lab day for each student. In a first research project, a digital learning module is designed. Learners are to select different tasks with optional learning aids along a differentiation matrix and switch flexibly between classic student lab aspects such as experimenting in the lab and digital tasks. This module will be piloted with students, student teachers and teachers. Evaluation and the accompanying research project will be addressed in this article.*

Keywords: *teaching chemistry, student laboratories, digitalisation, innovative learning materials*

1. Introduction

Digital media have long since arrived in didactic chemistry research. This research is often linked to the goal of improving the classroom experience and the students' understanding of chemical content. For example, digital media can have a supportive effect by providing multiple representations, contribute to the motivation of learners or lead to a transformation of the teaching and learning culture [1]. As students are potentially given the opportunity to control their own learning process through digital media, *i.e.*, in flipped classroom arrangements, the role of the teacher also changes towards a learning support role. The timing and extent of support needed could be determined by the learners themselves. If this succeeds, new media can make an important contribution to the individualisation of teaching and to the much-demanded differentiation in heterogeneous learning groups [2].

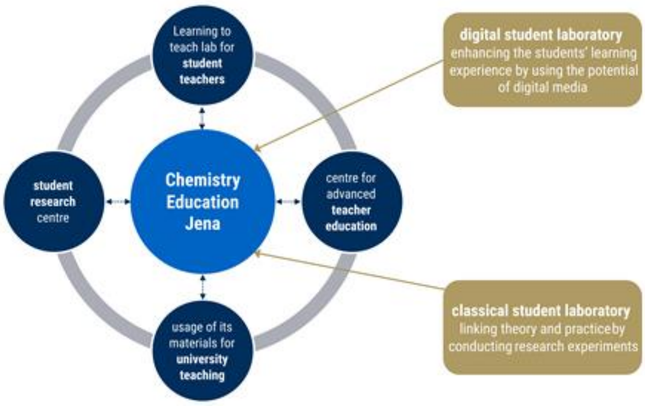
At the Friedrich Schiller University of Jena, a student laboratory is being established that uses and researches the potential of digital media for teaching and learning and promotes the improvement and transformation of current learning settings [3]. This *digitalchemlab* is a supplement to the already existing, classical student laboratory. With this, digital media can be used to make the student lab day as interesting as possible and to tailor it closely to the learner’s needs. For this purpose, a digital learning module is designed and piloted with students, student teachers and teachers. The concept of the *digitalchemlab*, the planned pilot learning module and the associated research project will be presented in the following.

2. Concept of the digital chemistry student laboratory Jena (*digitalchemlab*)

The planned digital student laboratory is a spatial addition to the already existing, classical student laboratory (Fig. 1). While the focus of the classic student lab lies on conducting experiments, their documentation and analysis, the digital student lab is intended for working on supplementary and in-depth tasks on the respective topic. Further, iPads will be used in combination with digital media and learning tools in both areas to improve the quality, individualise the learning pathways and measure the learning outcome of the laboratory course. The new laboratory is to be used for student laboratory visits, teacher training as well as for university teaching in the format of a learning-to-teach-laboratory [4].

Fig. 1: Model sketch of the planned digital student laboratory

From the perspective of student lab research, establishing a digital student laboratory offers many advantages and opportunities: (a) the influence on student interest [5] through student lab visits, which has been investigated by various studies, could be strengthened through the use of digital media, (b) the cooperation of schools and university can be improved through the development of digital and hybrid learning modules, and (c) student lab visits can become more flexible by a broader offer of *i.e.* online and face-to-face courses, and thus (d) more easily attended multiple times. This could help to amplify initial positive effects on interest and ability self-concept in the field of science [6].



(**Fig. 2:** Overview of services offered by the Chemistry Education Department)

In addition, student laboratory research can be further differentiated by the investigation of those elements, which influence the visitors, and expanded to include the effects of digital media usage. New digital tools, teaching-learning formats and teaching offers can be developed especially for the *digitalchemlab* and tested directly there. This favours their empirical research as well as their optimisation for practice. To investigate these aspects across the range of STEM subjects, various collaborations have already been agreed with the education departments of other natural sciences (mathematics and physics), the educational sciences and the educational psychology. The digital student laboratory is intended to benefit all offers of the Chemistry Education Department Jena (Fig. 2). With this mind, a first learning module was designed to explore the potential of the new digital student laboratory.

3. Creating a digital learning module on the topic of “household cleaners”

For the practical testing of the *digitalchemlab*, a first research project is dedicated to the creation of a digital learning module. The topic of household cleaners was chosen for this as one close to everyday life with great curricular relevance and direct application possibilities. The module follows a "chemistry in context" approach [7] and involves mostly simple experiments with generally harmless chemicals.

The learning module is based on an existing learning set from the classic student laboratory. For this purpose, the experiments were reworked, supplemented with accompanying tasks, and methodically given a new form. Instead of simply working on different stations, the students can now progress in the learning module along a so-called differentiation matrix [8]. A differentiation matrix is a method of differentiated or inclusive teaching. It combines elements of cooperative learning and individualisation and is based on KUTZER's learning structure grid [9]. The aim of a differentiation matrix is the preparation of a learning object from different perspectives, to challenge and encourage the learners [10]. The teacher takes on an adaptive-supportive, advisory-guiding role, which fits very well to the approach of student-centred learning with the help of digital media. The students work on the differentiation matrix in any order they like. Not every field has to be used, tasks alternate between individual, partner or group work.

	A. Classification and contents of household cleaners	B. Acids and bases combat dirt	C. Acid-Base-Chemistry made easy
Analysing/ Creating	Further household cleaners (15 min)	Tensides – tools for every use? (15 min)	Calculating acid and base proportions (15 min)
Applying	Ingredients of household cleaners (20 min)	Cleaning the drain (effects of alkaline cleaners) (20 min)	Neutralization of a drain cleaner solution (20 min)
Understanding	pH-value of household cleaners (10 min)	Decalcifying and derusting (effects of acid cleaners) (20 min)	Conductivity of washing powder and washing solution (20 min)
Knowledge	Classification of household cleaners (15 min)	Stain-free with acids and bases (10 min)	Acid-Base-Chemistry and household cleaners (10 min)

Fig. 3: Differentiation matrix of the digital learning module

For the cognitive complexity, which is arranged vertically, four fields were distinguished according to BLOOM [11] (knowledge, understanding, applying, analysing/creating). For thematic complexity, which is arranged horizontally, the topic was divided into "Classification and contents of household cleaners", "Acids and bases get rid of dirt" and "Acid-base-chemistry: made easy!" (Fig. 3). Two different types of tasks are included, each to be performed either in individual/partner work (digital tasks) or in partner/group work (experiments).

The learning module is eBook [12] based, so that students can navigate through the differentiation matrix again and again using their iPad and the eBook's user interface and explore the tasks of each field. On each field of the matrix there is a rough time estimate, a description of the task, and a characteristic picture. Different material is embedded via internal links such as instructions for the experiment as well as an interactive protocol for the experiment, explanatory videos, or interactive tasks (Fig. 4). Solutions are also available for review, information and help buttons enhance the offer. However, all fields are also set up in the real world, so that the students must move from place to place to complete the tasks. It is therefore a hybrid learning offer (real-live experience mixed with digital elements).

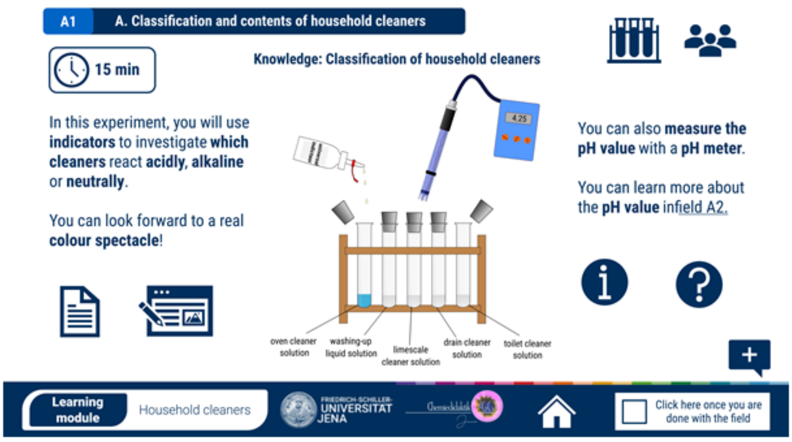


Fig. 4: Excerpt of the digital learning module

The entire student lab visit typically lasts between three and four hours. A pre- and post-visit learning module are planned to embed the visit in the school context and promote knowledge retention [13]. The learning module described will be piloted in 2022, depending on the pandemic situation. The research project planned for this will be briefly presented below.

Fig. 5: Students piloting the experiments on household cleaners

4. Planned research project

The experiments of the learning module have been tested over the past three semesters with student teachers (Fig. 5). The complete learning module will be tested with three to four school classes and is planned for the summer of 2022. One school class will serve as a control group that will carry out the learning module without the digital elements and tools but with the same tasks, all analogue. The research project is supported and accompanied by the department for educational psychology [14]. The aim is to investigate the knowledge gain, the use of the offer as well as the motivational orientation of the participants. Both qualitative and quantitative research methods will be used.
Two main research questions are currently being inquired:

(1) What influence does the hybrid learning module “household cleaners” have on the increase in knowledge and the current interest in science?
(2) How is the offer used (learning types/ways) and is there a dependency on prior knowledge?

First results should provide indications for improving the offer, which will then be tested and evaluated in a main study after a revision phase.

5. Conclusions and outlook

A digital student laboratory offers a variety of potentials both in terms of organisation and content. The specific focus on digital media can be used to promote new teaching-learning concepts and make important contributions to differentiation in heterogeneous learning groups. The planned hybrid learning module on the topic of “household cleaners” is a first building block for the creation of learning offers in the digital student laboratory and serves as a model. If piloting and evaluation are successful, further learning modules based on the new concept will be created and the offer will be expanded to include further training for teachers on the topic of digital media in chemistry lessons and the use of digital differentiation matrices. In this way, the digital student laboratory can be used to further advance digitalisation in chemistry teaching and the student laboratory.

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