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The Application of Learning Management Systems in Chemistry Teacher Trainees’ Practical Courses

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Abstract

During the last few years learning management systems, such as Stud.IP, Moodle or ILIAS have gained an increasing acceptance as supporting tool for teaching at university. Thus, these systems are already used intensively for the management and distribution of teaching materials, like lecture notes, documents and exercises, as well as for the extensive administration of courses. Additionally, attractive teaching materials containing multimedia-based elements and interactive components can easily be created by utilization of such systems. In the following article, the Cognitive Theory of Multimedia Learning (CTML) is briefly depicted. Then, for a general understanding of learning management systems, a short report on the ILIAS-learning software is given. After that we present how learning management systems can be used to implement training videos and new types of tasks to help students acquiring practical skills in the laboratory. Based on this, we present an ILIAS-conception for a beginner’s laboratory course for chemistry teachers. At the end of the course that concept was evaluated with a questionnaire study concerning the subjectively-felt-quality (N=52). The results of this study reveal that first-year students are able to develop a more precise idea of the laboratory’s procedure, are feeling better-prepared and are more confident in their practical operation compared to script-based learning.

Keywords: Teacher Education; Learning Management Systems; ILIAS Learning Software; Multimedia-Based Elements; CTML

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1. Introduction

The use of new media such as the internet has a great didactical potential in school, business and university education. In this context, many universities recently established E-learning-Centers, which support the development of multimedia learning materials, Blended Learning scenarios and distribution of Podcasts. Moreover, they assist the recording and implementation of E-Lectures. These presentations of information with the help of new media is often used in chemistry fundamentals courses, e.g. in the CHEMnet-Project at the IPN in Kiel, the ELAN III-Project Exchem at the University of Göttingen and the E-Lectures of the Internet-Multimedia-Server at the University of Tübingen. The recorded lectures and materials are distributed among students by Learning Management Systems (LMS) such as Stud.IP, Moodle or ILIAS and can be used and maintained online. Most of the LMS also have additional software tools for the design and control of learning processes:

- Tools for visual assistance of presentations
- Tools for creating exercises
- Tools for evaluation and comments
- Tools for communication and
- Tools for course administration

Referring to the paper’s topic – the support of chemistry practical courses – the multimodal possibilities of presentation and the development of creating exercises are focused. The diversity of suitable media as texts, pictures, animations and videos and the variety of possibilities to create exercises enable the activation of different cognitive operations on the learners’ side. Therefore not only the acquisition of cognitive-rational but also psychomotor skills can be supported, which are necessary for practical chemistry work. The basic theory of multimedia learning is the Cognitive Theory of Multimedia Learning (CTML) proposed by MAYER (2005). According to that, the processing of information involves a sensory memory, a working memory and a long-term memory.

![Diagram of the Cognitive Theory of Multimedia Learning](image)

Fig. 1. Processing of information according to the Cognitive Theory of Multimedia Learning by MAYER (edited and translated)

As shown in fig. 1, CTML states that information can be gathered through an acoustic and a visual channel. The following processing takes place in the working memory: the sensory information needs to be selected and is then transformed into an acoustic representation (sounds) and a visual representation (image), which can be translated into each other according to PAIVIO’S (1986) dual-coding-theory. After that, the representations are transformed into verbal and visual models. Finally these models can be
integrated into the knowledge and transferred into the long-term memory. Thus the processing of information is achieved by a dual system and MAYER also stresses that both channels have a limited capacity, which leads him to recommendations on the design and presentation of multimedia learning material in order to prevent ‘cognitive overload’ (MAYER 2008). In terms of SWELLER & CHANDLER, this kind of cognitive load can be described as extraneous cognitive load, which should be minimized. Therefore, in practice, videos should be segmented or students should be given control over the progression of the video. Furthermore, the principle of dual coding suggests a verbal and pictorial presentation of information and the principle of modality suggests spoken instead of written text in videos and animations in order to use both channels. Finally, visual and acoustic information should be given at the same time, which is requested by the principle of contiguity.

The high value of multimedia and digital learning materials referring to psychomotor skills is also shown in its enormous area of deployment, e.g. in the fields of sports teachers’ education segmented video instructions called cues are used to train and optimize psychomotor tennis or golf skills (MÜLLER & DANISCH 2007) or in the fields of medical education videos are used to learn surgery skills (ALLEN & CHAMBERS 1997). Taking this into consideration, students can be supported by preparing chemical practical courses with the help of videos or animations including the handling of laboratory equipment such as gas bottles or measurement devices or the process of experiment executing and experimental setups. Referring to the last two items, videos and animations that show the safe handling of hazardous materials and experimental setups by considering ‘perception laws’ might have a greater impact than printed practical course scripts according to the dual channel procession of information in the CTML. Particularly by using awareness leading techniques as zooming, slow motion or voice-over-comments in the post production of videos, the difference to a simple script might grow. In advance, students can choose their own viewing preferences according to their knowledge and individual speed of information processing e.g. by concentrating on certain aspects of a video or watching parts of it again. Especially in beginner’s practical courses students are usually not familiar with the laboratory equipment and do not have experimental skills. This way they can benefit from digital learning material and gain an idea of laboratory work, which also has an influence on the aspect of security during the course.

In the following we describe the main functions of LMS ILIAS and sum up our experiences with a preparatory learning design in a beginner’s practical course for chemistry teachers. Finally, we will present the outcomes of a survey among students on the efficacy of the online learning design vs. a common practical course script.

2. The LMS ILIAS

This chapter gives a brief description of our experience with the main functions of LMS ILIAS; more detailed information are given by Kunkel (2011) or the official website http://www.ilias.de/docu.

The user interface of ILIAS mainly consists of a personal desk, the stacks and the mail area. After login the user is directed to his personal desk where he has an overview of his created files, new mails and personal notes as well as users who are simultaneously online. In addition, a calendar is available, which can be used for course organization.
Fig. 2. Screenshot of the ILIAS-User-Surface: “Persönlicher Schreibtisch” (personal desk), “Magazin” (stacks), “Meine Angebote” (my created files), „Kalender“ (calendar), „Notizen“ (notes).

The stacks organize the learning contents according to the levels of departments, subjects and categories. Within the categories learners can use questionnaires, forums, chatrooms and digital learning units, which can be created with the help of an online-editor. The structure of a learning unit can be compared to the structure of a book, divided into chapters and pages with an automatically-created directory. The learning contents can be presented in four kinds of standard layouts:

![Standard Layouts of the ILIAS Learning Units](image)

Fig. 3. Standard Layouts of the ILIAS Learning Units

Not only is it possible to present text (1window and toc2win) in a learning unit but you can also combine textual elements with other media such as pictures, videos or animations (2window and 3window). Using the implemented online editor, one can easily create various learning modules and exercises. The different exercises are collected in a pool of questions and can thus be used for creating online tests. Eight different types of exercises can be authored using the implemented WYSIWYG-editor...
including multiple-choice questions, true/false questions, matching tasks, fill-in-the-blank and free text exercises, which can be corrected automatically to a limited extent. In addition to that, exercises can be equipped with an answer-sensitive feedback or a sample solution. In our opinion, the image-map tasks deserve most interest. Those are either pictures or graphics in which various clickable pads can be defined, amongst which learners have to find the sought pad. Exercises of this kind could be the search for mistakes in the setup of an apparatus or marking specific functional groups within a complex molecule.

Furthermore, ILIAS conforms to the SCORM standard (Sharable Content Object Reference Model) of the ADL (Advanced Distributed Learning Initiative) that allows web based learning contents to be exchanged and altered on different platforms. This enables earlier created learning contents to be reused, enhanced and adapted specifically to respective didactical settings. The handling of LMS ILIAS is basically self-explanatory. Therefore, it is not necessary to have knowledge of HTML programming for creating learning modules.

Yet the variety of functionalities in ILIAS involves the risk of losing the overview. We therefore advise every user to familiarize with the system for half a day before creating learning units in ILIAS. Apart from that, the structure of the LMS leads to a strict separation of tests and learning modules, which, in our opinion, does not ideally support learning progression. So far, tests cannot be implemented into the ILIAS learning module directly resulting in a restricted interactivity. Admittedly, the possibility for embedding tests by using hyperlinks exists, but this leads to inconvenient navigation. Nevertheless, we can sum up that on the one hand working with ILIAS is easy to learn and accomplish and on the other hand provides useful tools for creating varying learning units that consider the proposals of CTML.

3. Usage of an ILIAS-learning unit in a teacher trainees’ practical course

Prime objective of the chemistry practical course for teacher trainees is the acquisition of experimental competence in the context of chemical school experiments. According to the proposals of the MNU (a German association for math and science teaching; 2004) students training to be chemistry teachers should learn to understand and exercise standard experiments with school specific materials and laboratory equipment. This includes consideration of ‘perception laws’ in the setup of demonstration experiments as well as mastery of the performance and evaluation of quantitative experiments, miniaturized experiments and low-cost-measurement devices. Apart from psychomotor skills an important aspect of experimental competence is security awareness, i.e. knowledge of the GHS hazardous symbols, laws concerning the use of chemicals in school, assessment of risk factors of experiments and proper disposal.

The course design we created with ILIAS is based on traditional practical course scripts and contains learning units for every experiment including chemicals and laboratory equipment, setup, performance, didactical clues, security aspects and clues about analysis and interpretation of the results and disposal. In addition, every learning unit contains graphics of the setup and a video about the usage of the laboratory equipment and the chemicals in order to setup and perform the experiment.

For the production of the videos we acknowledged the proposals of MAYER (2008) to avoid cognitive overload. The units are followed by an informal test including questions about theoretical aspects, i.e. chemical and didactical basics such as the exercise to assign the chemical contents to the curriculum, as well as practical aspects of experiments. For this purpose we use image-maps in which the learner is
supposed to spot typical mistakes in the experimental setup. An example of a video and a test is given in fig. 4.

Fig. 4. ILIAS-unit with integrated video (left) and image-map test (right).

4. ILIAS learning units vs. traditional course script – study design and sample

To compare the ILIAS learning units and practical course script as learning methods we conducted a study using questionnaires asking about the subjectively felt quality: What is the effect of our multimodal designed learning units in students’ opinion? For this purpose we designed a test in which students had to perform two experiments after having prepared them with either an ILIAS learning unit or traditional course script. The experiments were the synthesis of ethene and the synthesis of crude iron. Afterwards the students were given a questionnaire with seven items on the students’ opinion concerning their confidence when conducting the experiments and a Likert-scale with five possible answers from “do not agree at all” to “I fully agree”. The questionnaire was kept short to increase the motivation for answering the questions.

The group of students taking part in the study was divided in half and had to prepare themselves according to the cross-over-design:

<table>
<thead>
<tr>
<th>Group 1</th>
<th>Production of Ethene</th>
<th>Production of Crude Iron</th>
</tr>
</thead>
<tbody>
<tr>
<td>ILIAS-unit</td>
<td>Script</td>
<td>ILIAS-unit</td>
</tr>
<tr>
<td>Group 2</td>
<td>Script</td>
<td>ILIAS-unit</td>
</tr>
</tbody>
</table>

Table 1: Cross-over study-design for the preparation of the practical course
Because the requirements of the two experiments concerning the use of laboratory equipment and the performance were similar and every group has to prepare in both ways (see table 1), every group is its own controlling group towards a preferred kind of preparation. In order to minimize effects of software knowledge and skills, all students received a brief introduction to the ILIAS-Software and largely homogeneous groups were formed. The criteria for group formation were age, sex, semester, E-learning-experience and course of study:

<table>
<thead>
<tr>
<th>N</th>
<th>Age ±</th>
<th>Sex</th>
<th>Semester ±</th>
<th>E-learning-experience</th>
<th>T1 / T2 / T3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1</td>
<td>25</td>
<td>22.2 ± 2.8</td>
<td>9 / 16</td>
<td>2.08 ± 0.4</td>
<td>88 %</td>
</tr>
<tr>
<td>Group 2</td>
<td>27</td>
<td>24.0 ± 5.9</td>
<td>11 / 16</td>
<td>2.14 ± 0.9</td>
<td>86 %</td>
</tr>
</tbody>
</table>

Table 2: Data of the homogenized groups; N = number, T1 = “Secondary modern school teacher”, T2 = “grammar school teacher”, T3 = “vocational school teacher”

In order to avoid sequence effects both groups again were divided with one half starting with the ethene-experiment and the other half with the crude iron-experiment:

<table>
<thead>
<tr>
<th>Group 1</th>
<th>13</th>
<th>Ethene (ILIAS-unit)</th>
<th>Crude Iron (Script)</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>Crude Iron (Script)</td>
<td>Ethene (ILIAS-unit)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Group 2</th>
<th>13</th>
<th>Ethene (Script)</th>
<th>Crude Iron (ILIAS-unit)</th>
</tr>
</thead>
<tbody>
<tr>
<td>14</td>
<td>Crude Iron (ILIAS-unit)</td>
<td>Ethene (Script)</td>
<td></td>
</tr>
</tbody>
</table>

Table 3: Order of the experiments to avoid sequence effects

All students got the same instructions and had to prepare the experiments in a period of three hours before the start of the laboratory phase. They used identical computers with high-speed internet access and identical scripts.

Through these precautions – the control groups because of the cross-over-design, the comparable group formations, the identical performed experiments, the efforts to avoid sequence effects and the identical preparation time and circumstances – main aspects of a comparison of two learning methods were considered (BORTZ & LIENERT 2003).

5. Results and Discussion

We conducted a survey to compare the concept of ILIAS-units with script-based preparations for practical courses as related to the subjectively felt quality of the two learning methods. Since the response rate of the survey amounted to 100%, the general willingness to participate in the study is obvious and all questionnaires could be used for interpretation. The raised data were analyzed by use of OriginPro 8.5 and compared by employing MooD’s Median-Test. In relation to our preliminary considerations concerning the influences of the complexity of the experiments in comparison to each other or the order
of their implementation, there were no statistically significant dependences to be found in the subsequent analysis. An influence of those disturbance variables on the following results can therefore be excluded to a large extent. Fig. 5 shows the items of the survey as well as the averages and distribution in reference to the subjectively felt quality of the two learning methods.

![Diagram showing survey items and results](image_url)

**Fig. 5. Items and results of the questionnaire survey (*p < 0.001*)**

As can be seen from the fig. 5, all items feature clear differences in the averages that are statistically significantly high to all pairs (*p < 0.001*). The averages of the conventional preparations for the practical course, positive and negative statements counted in, reside between 2 and 3 on the five-digit Likert-Scale. Thus, the subjectively felt quality of the preparations for the conventional script is located in the lower to neutral area. This learning method is rated neither very good, nor very bad amongst beginners. Compared to the preparation with e-learning, a wider distribution of opinions can be found in the scripts approach as can be seen in item 2; the consensus that can be drawn from the quality of the conventional preparations is rather small.

Additionally, significant differences between students of different courses of study can be observed as well (*p < 0.05*). Students training to be grammar school teachers rate the preparation with the script slightly higher than students who want to teach at secondary modern school (3.2 ± 0.90 vs. 2.8 ± 0.88). We think that those slight differences derive from experimental experiences that are a result of different ranges of laboratory practice within the basic chemistry studies. Especially practical courses in physics and inorganic chemistry take up considerably more teaching time in teacher education for grammar schools.
Furthermore, there are gender-specific differences to be observed concerning the work with traditional scripts in item 2, 3 and 5 (see table 4). Male participants of this study rate the preparation with the script slightly better than female participants. This gender difference cannot be noticed within our ILIAS-concept.

The interpretation of the LMS based preparation generally draws a positive picture for the subjectively felt quality. The averages of the positive statements vary between 4 and 5; averages of the negative statements between 1 and 2. This result is supported by the fact that 98% of participants would favor the E-learning approach in practical courses to come, although preparation using E-learning takes up more time than conventional preparations. Hence, the acceptance of this approach seems to be high enough to tolerate a greater time need.

As shown before, the analysis of the E-learning preparations concerning course of study and gender shows no significant differences within the items, as opposed to the script-based preparation. In our view and in context to the previous findings, a distinctive trend for harmonizing various learning requirements can be found in the preparation with our ILIAS-concept. Yet positive responses for learning methods including new media also often correlate with the novelty effect (KERRES 2003). Here, innovative and more unusual forms of learning lead most notably to an increase of motivation, which can ultimately result in a more positive assessment of this ‘new’ learning method. From our point of view, this effect can only have a marginal influence on the results, since more than 86% of the participating students had already gained experience in E-learning before (see table 2).

Thus a positive appreciation regarding the subjectively felt quality of E-learning can generally be drawn from our study. How far this subjective impression actually results in more effective work in the laboratory will be a topic of further studies. However, based on our observations, the preparation with E-learning units compared to the script-based preparation also resulted in superior laboratory work. We conclude this from less mistakes, problems and security risks while the experiments were conducted. To back those observations, a scientifically evaluated testing instrument to examine the sustainability of these learning modules should be rendered in the future. During the study, the question whether practical courses could be replaced by this type of program came up occasionally. But most of the participants judge this aspect critically. Firstly, most students are aware of the fact that the skills they ought to learn can only be obtained through exercises. Secondly, the E-learning program seems to provide the students with more motivation for autonomous acting. The reprocessing of the experiments by the means of the new media seems to have a stimulating nature for autonomous acting rather than leading to the acceptance of digital replacements. Differentiated assertions for this will be made in the future as well, since this aspect is dependent on various factors like the complexity of an experiment, the temporal

<table>
<thead>
<tr>
<th>Gender</th>
<th>Method</th>
<th>Item 2</th>
<th>Item 3</th>
<th>Item 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>m</td>
<td>ILIAS-unit</td>
<td>4.8 ± 0.36</td>
<td>2.9 ± 0.64</td>
<td>4.2 ± 0.61</td>
</tr>
<tr>
<td></td>
<td>Script*</td>
<td>3.4 ± 0.94</td>
<td>4.2 ± 0.69</td>
<td>3.1 ± 0.85</td>
</tr>
<tr>
<td>f</td>
<td>ILIAS-unit</td>
<td>4.8 ± 0.36</td>
<td>2.7 ± 1.01</td>
<td>4.5 ± 0.67</td>
</tr>
<tr>
<td></td>
<td>Script*</td>
<td>3.0 ± 0.91</td>
<td>4.5 ± 0.62</td>
<td>2.8 ± 0.64</td>
</tr>
</tbody>
</table>

Table 4: Results of items 2, 3 and 5 with regard to gender (* = p < 0.05)
learning effort, the effects of experiments, the scholar relevance and the previously made experiences of the students.

Despite the overall positive results of this pilot study we see this kind of preparation with E-learning critically due to economically reasons. The effective media- and subject-didactic creation of multi-media materials – taking all suggestions of CTML into account – is connected with enormous temporal efforts in the beginning. Furthermore, comprehensive chemistry didactical knowledge is needed. From our point of view, there are more valuable, circumstanced and application-oriented learning opportunities, especially for those students in higher semesters, which justify extra effort and expense. In connection to that, we got a lot of positive feedback by students that already used such learning modules and want us to broaden and deepen those concepts.
References


