Comprehensive Virtual Mathematics Training

A crucial support to bridge the gap for undergraduate students

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***Abstract*—We present an integrated virtual learning based approach to support undergraduate students in developing their mathematical knowledge and skills. The approach consists of three elements. First, a pre-study web-based mathematics training course for pre-assessment and self-study. Secondly, the traditional classroom lecture that is supplemented with specific examples from application fields involving dedicated literature and case examples from other courses (e.g., physical chemistry). Finally, lectures have been recorded using an easy-to-use system to provide the students with after-class self-learning material. The latter proves especially useful for extra-occupational students. The approach has been developed and implemented for chemistry undergraduate courses but can be easily adapted for any kind of engineering study course.**

***Index Terms*—mathematics; e-learning; virtual learning; self-learning; computer algebra system; lecture recording; extra-occupational students; ILIAS; Opencast Matterhorn**

I. INTRODUCTION

High-developed economies depend much on junior scientific staff in the so-called MINT disciplines (Mathematics, Information Sciences, Natural Sciences, and Technology). Mathematical competencies are of critical importance to master any degree course in these disciplines [1]. However, students today seem to be less prepared to meet the challenges of this abstract subject. On the one hand, mathematical literacy of German high school graduates is reported to have declined [2-3]. On the other hand, a rising demand for extra-occupational programs brings in students who are not used to abstract mathematical thinking from their everyday working environment [4]. Mathematical illiteracy is thus seen as one of the reasons for a rising drop-out rate in natural science and engineering study courses. This exacerbates the structural deficit among graduates in the MINT disciplines and leads to a shortage of skilled staff not only in Germany, but also in other European countries [5].

It is thus important to address the challenge of increasing the mathematical literacy of students, especially undergraduate students, in their first year of studies. To increase the learning progress and sustainability in mathematical education, it is essential to repeat learning content frequently and practice exercises intensely. However, the high demand for such thorough education usually cannot be met due to limited human resources ("number of lecturers") at higher education institutions. Therefore, information and communication technology (ICT) based training and practice could be envisaged to support overcoming this limitation. In this paper, we present our multi-level approach to address the problems described above using ICT in mathematical teaching. It consists of three elements (see Fig. 1): first, a pre-study web-based mathematics training course for pre-assessment and self-study. Secondly, the traditional classroom lecture that is enriched with various interactive elements and supplemented with specific examples from application fields involving dedicated literature and case examples from other courses (e.g., physical chemistry). Finally, the third element consists of lecture recordings in combination with an interactive web based script to provide the students with after-class self-learning material.

II. METHODS

For the pre-study mathematical learning material we used the web-based training course OMB ("Online-Mathematik-Brückenkurs", online math bridge course) that was provided by TU Berlin [6]. The OMB is part of the open-source e-learning platform MUMIE, a web-based learning- and teaching environment specialised in mathematics and mathematical sciences [7]. The OMB consists of two parts and two supplementary modules. Part one deals with the basic topics of arithmetic and algebra. Part two covers roots, logarithms, trigonometry and differential calculus. The modules deal with advanced topics such as integration and complex numbers. All parts, and the modules, contain chapters that are divided into several sections. Each section contains a theoretical part with many examples, exercises, a diagnostic test and a final exam. At the end of each main part there is a final term paper which is graded by the OMB mentors. Furthermore, the OMB is accompanied by a mentored forum where the participants can discuss with each other. Students can access the course via a weblink on the homepage of the Fresenius University of Applied Sciences [8]. Working through the course was not an obligation, but was recommended for all participants prior to their studies.

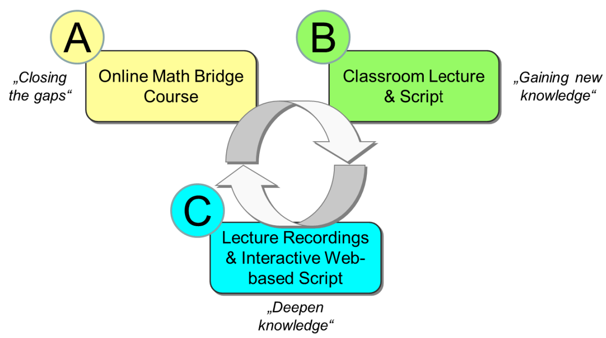

Figure 1. Three elements to improve mathematical literacy for undergraduate students.

The on-site lecture was conducted using a smart board ("SMART Podium interactive pen display", [9]), so that static presentations and software demonstrations could be enriched *ad hoc* with calculations, plots or annotations to illustrate complex subject matter. Additionally, the lecture was accompanied by an interactive online script that was derived from a LaTEX script which was transformed by a LaTEX-XML converter into multiple XML/XHTML documents and enriched with specific exercises. These documents were stored in a database and presented to the students via a web interface by an in-house Java-based web application named "SciChat". Furthermore, the "SciChat" web application was linked to a computer algebra system (Maxima, [10]), so that the students' response in the exercises were automatically evaluated to be correct/incorrect and specific feedback could be given to the students in an automated way.

Lectures were recorded using an Epiphan lecture recorder system [11]. Depending on the specific needs and situation, the system could be connected to different input systems, such as video, audio, a smart board or a personal computer. Thus, all actions including calculations, plots and annotations that were carried out on the smart board during the lecture were captured together with the aural explanations of the lecturer, and stored. The recorded lectures were uploaded to a media server and processed with the web-based video management system "OpenCast Matterhorn", an open-source software to support the management of educational audio and video content [12]. After trimming/editing of the raw lecture recordings online, an automatic scene detection and slide preview generation was applied, and finally the streamable format(s) were generated and stored on our media server. The recordings were made accessible for the students via IFRAME embedding in course objects of the in-house learning management system ILIAS ("Integriertes Lern-, Informations- und Arbeitssystem") [13].

III. RESULTS AND DISCUSSION

Our multi-step approach to smooth the transition from the school or working environment to the lecture hall consists of three core elements and utilises the broad potential that modern ICT offers (see Fig. 1). This integrated teaching scenario was implemented in the winter term 2012/13 and further development and optimisation was carried out during the whole term. Therefore, only first results can be presented here. Based on experience gathered, addititional improvements will be undertaken in the upcoming degree courses which will start in the next winter term 2013/14.

A. *Pre-study online math bridge course (OMB)*

The first element consists of a web-based training course that is provided prior to the first semester for new students. We currently rely on the ready-to-use OMB course (see above). This course allows students a self-assessment of their mathematical skills before uptake of the study course (see Fig. 2). Furthermore, the course provides material to cover existing gaps and supports the math preparation course that is usually held one week before start of the semester.

Information about the course was given to the students of the degree courses Industrial Chemistry (B.Sc., extra-occupational), Business Chemistry (B.Sc., full-time) and

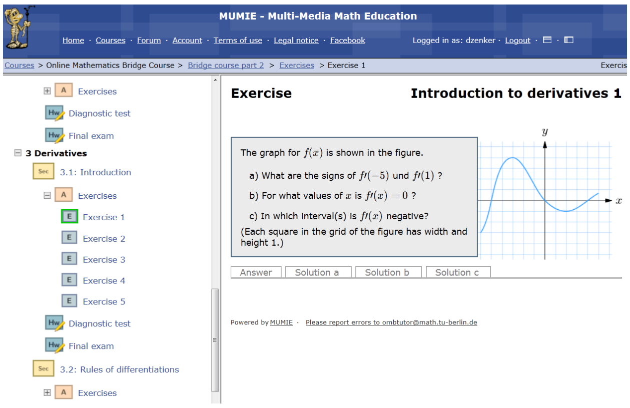

Figure 2. Self-assessment Exercise in Part 2 of the Online Math Bridge course (OMB)

Applied Chemistry (B.Sc., full-time) prior to their studies partially by written communication, and by oral announcement and information on the University homepage. By the end of November 2012, 30 students applied for an account for the OMB course, which represents a share of 64% of the total number of students (47) in the three degree courses. The user statistics showed that half of the registered students logged into the OMB for at least one more time after account registration. Six students (20% of the registered students) passed several exercises of part 1, and two students (7% of the registered users) completed the final term paper and thus finished this part. However, only two students (7% of the registered users) worked to some extent on part 2 of the OMB, and the supplementary modules have not been used to date.

One possible reason for the rather low usage of the OMB is that the information about it was submitted too late for anything but oral announcement. For instance, a portion of the students signed their study contract just a few days before the start of the semester. Therefore they could not be informed by written communication. Another reason was especially in the extra-occupational degree course Industrial Chemistry (B.Sc.), that the students were subjected to a huge workload, and thus they did not immediately realise the advantage of the OMB due to time constraints.

B. *Classroom Lecture*

The second element is the traditional classroom lecture that is enriched with various interactive elements. New knowledge is taught step by step and also involves examples from application fields. These examples either stem from dedicated literature (such as "Maths for chemistry") or from integrating case examples from courses in higher semesters that rely on the mathematical knowledge and competencies to be developed (such as physical chemistry or process technology). The usage of a smart board during the lecture offers new options to make it more diversified and lively, a prerequisite for increasing the teaching effectiveness of the more abstract mathematical learning content.

C. *Lecture recordings and web-based interactive script*

The third element consists of recording the classroom lecture using an Epiphan lecture recorder system. The system is easy-to-use in order to minimise the hurdle for the lecturer to apply it in the lecture hall setting. Further processing of the recordings is also an easy task, since this can be done quickly and comfortably using the OpenCast Matterhorn web application (see Fig. 3).

As a result, the recorded lectures can be presented to the students shortly after the lecture in order to give them the opportunity to work through the material again at their own learning speed. This option is especially important for students who follow an extra-occupational program as they cannot be present for each lecture during the semester (e.g., due to company restraints such as shift work). Furthermore, OpenCast Matterhorn offers a rich media user interface for learners to engage with academic video content, including slide preview, content-based text search, an annotation feature for scene-specific comments and discussion, and other features (see Fig. 4).

All examples and exercises that were discussed in the lecture could be repeated and used for training by the students at any time using the interactive online script "SciChat" (see Fig. 5).

In total, 16 lectures with a total time of about 32 hours were recorded, resulting in about 42 gigabyte of raw video data that was further processed with the OpenCast Matterhorn video management system and finally made accessible for the students.

D. *Feedback of the students*

In a first questionnaire which was carried out at the end of the first third of the winter term 2012/13, 14 students from the extra-occupational degree course Industrial Chemistry (B.Sc.) were asked about their usage and opinion of the various ICT based support offers described above. Finally, 10 fully completed questionnaires were further evaluated (see Fig. 6-8).

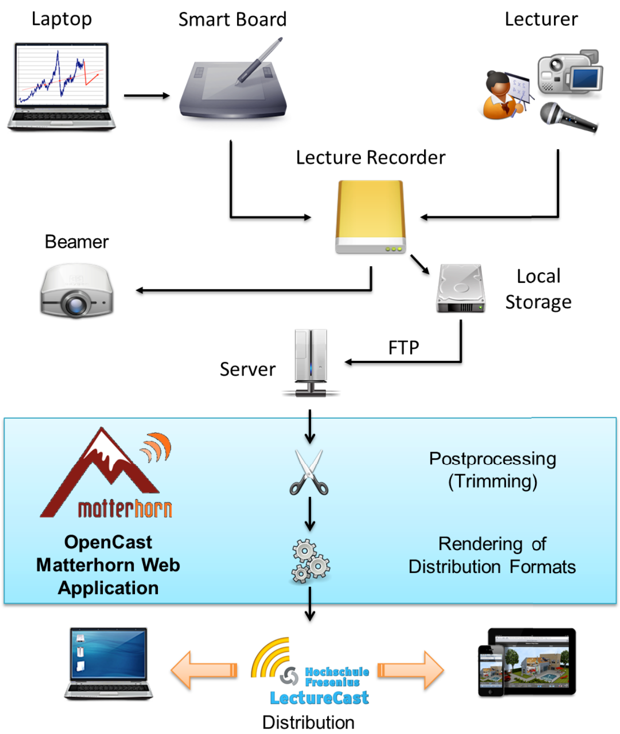

Figure 3. Schematic View of the Lecture Recording System and Workflow

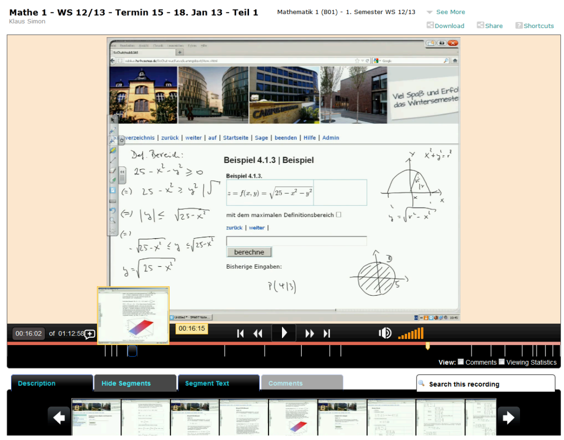

Figure 4. Extended View of the OpenCast Matterhorn Engage Player Interface

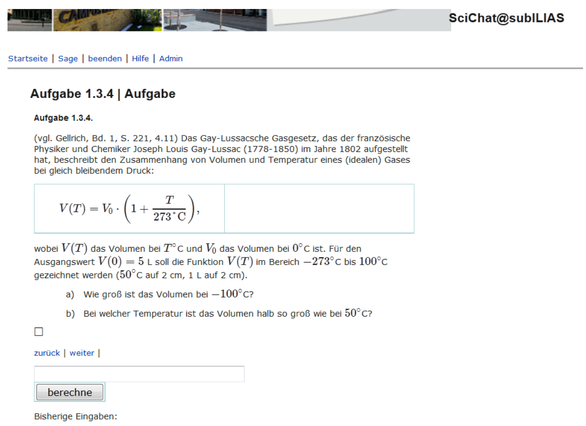

Figure 5. A "SciChat Interactive Script" Exercise with Input Field for Evaluation of the Students' Response with a linked Computer Algebra System

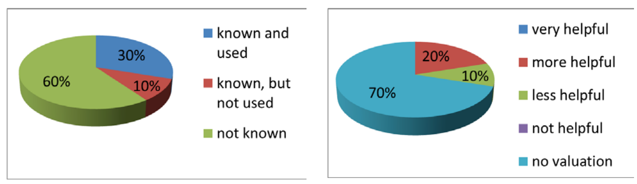

Figure 6. Usage and Opinion of the Students regarding the Online Math Bridge Course (n=10)

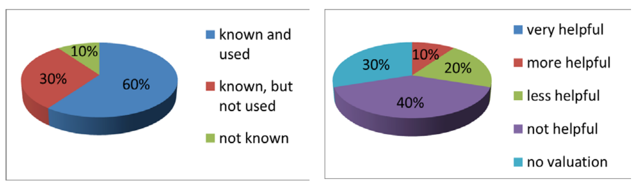

Figure 7. Usage and Opinion of the Students regarding the "SciChat Interactive Script" (n=10)

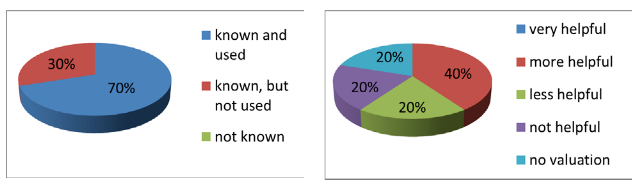

Figure 8. Usage and Opinion of the Students regarding the Lecture Recordings (n=10)

The results showed that the majority of the students were not aware of the online math bridge course, and thus it was not used and could not be rated. This was as expected from the usage statistics (see above).

None of the other two elements was considered to be "very helpful", and acceptance was moderate for the lecture recordings only, whereas the majority of the students rated the "SciChat Interactive Script" as "less" or even "not helpful". Though, implementation of all elements was accomplished shortly before start of the semester and further improvement and optimisation was in progress during the whole term.

IV. CONCLUSION AND OUTLOOK

To sum up, our findings suggested that the lecture recordings were more helpful for the students than the "SciChat" interactive script, probably due to the "dynamic" character of audiovisual content in contrast to the more static web-based script. As a consequence, we will consider connecting these two currently separate elements to form a more integrated online learning scenario. For example, one lecture recording could be split into several smaller sections, and each section could be linked to the corresponding exercises of the interactive script. Furthermore, the 'test & assessment' functionality of the learning management system might be used by combining these lecture recording sections with specific tests. By this alternating arrangement of a theoretical part with a subsequent self-assessment, the students will be able to trace their learning progress immediately.

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