EXPERIENCES WITH DESIGN AND USE OF LARGE COLLABORATIVE WORK AND LEARNING SPACES IN DIGITAL LEARNING LABS

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Abstract

The article reports experiences related to design, development and usage of a new flexible learning environment – the digital learning labs – where students are involved in a range of collaborative learning activities. The design takes into account both the physical and technical environment in order to enhance and facilitate students’ collaboration and communication.

The digital learning labs have been used for two years in a diverse set of subjects including language training, physics, mathematics and social sciences, but the focus of this article is on the use of digital learning labs in an introductory physics course for mechanical engineering students. Based on these experiences, we have been able to identify a set of critical success factors for the implementation of such learning spaces.

Keywords: Digital learning lab, iPad, interactive whiteboards, flexible learning environment, learning scenarios.

1 INTRODUCTION

The inception of the HiST digital learning labs was partly a desire to streamline the workflow of group-based, written exercises that are handed in each week as part of the course requirements. Traditionally, the students have worked these exercises on paper around a table, and the hand-ins have been delivered on paper. It was observed that the collaborative aspect was frequently lacking – although the assignments were handed in as a group effort, the students did not necessarily work on the exercises together as a group. Our working hypothesis was that student collaboration could be enhanced if the right infrastructure existed – a learning space with interactive whiteboards which would enable the students to collaborate effectively on a common problem or exercise.

Student motivation and engagement have a strong influence on learning, and the digital learning labs were constructed with an objective to support those factors, by creating an environment for active learning [1]. So far, there is limited research literature available about the use of interactive whiteboards and collaborative learning in higher education – existing literature tends to focus on K-12 education [2], [3], [4].

The construction of the pilot version of the labs was completed in time for the autumn term beginning in September 2010. As the experience in the use of the labs increased, various design issues and feature requests were identified, and based on both observations from teachers and technicians, as well as student surveys, the learning labs were revised to address these issues.

As experience with the use of the digital learning labs was gathered, more usage scenarios were discovered. At the moment, the labs accommodate a variety of teaching methods and usage scenarios – e.g. group-based exercises using interactive whiteboards; laboratory work; video conferences and research and development-related work. The process of revising the rooms for new usage scenarios is a continuous process, and during the spring term of 2012, the labs have been used as test beds for three projects funded by the European Commission:

- Global SRS [5], which continues development of a student response system (SRS) which has been used at HiST since 2009 (the prototype was developed through the Lifelong Learning project called Edumecca). The interactive whiteboards in the learning labs have been used for group votes during SRS sessions.
- Done-IT [6], which aims to develop an online assessment system for mobile devices. The digital learning labs have been used for the extensive prototyping and focus group tests during product development.
• EuroPlast [7]: in order to provide more practice-oriented training, the Activity Based Training (ABT) methodology has been developed. Originally developed in the Leonardo da Vinci Mecca project [8], the methodology is now being deployed to new disciplines. One of the latest extensions is for instance joining of plastic materials, which is the focus of the ongoing EuroPlast project. The main aim is to expand learning skills by use of ABT, and disseminate the inquiry- and problem-based blended learning training methods into Slovenia, Slovakia, Hungary and Norway. The digital learning labs will be used to develop the ABT methodology.

This article outlines the development process of the digital learning labs, from the pilot phase to the revised setup – a process which has been driven by feedback from both students, teachers and technicians. It also describes in detail how the learning labs have been used by physics classes of mechanical engineering students, and presents the results of two years of experience with this methodology.

2 DESIGNING THE DIGITAL LEARNING LABS

The digital learning labs were constructed by redesigning and refurbishing classrooms that already existed on campus. This approach introduced limitations regarding the placement, size and shape of the rooms, and also heating and ventilation (HV) placement and capacity. However, since new premises did not have to be construction from scratch, most of the budget could be allocated to technical solutions that would optimize the functionality of the digital learning labs.

Calculations were done to estimate the ventilation capacity, to ensure that it could handle the heat dissipated from video projectors and computers that would be installed. The air exchange was not as high as expected, but the HV system was still able to deliver a stable, adequately low temperature, which improved the experienced indoor air quality. Also, windows in the room could be opened to get fresh air.

The first version of the labs was constructed to have a capacity of around 35 students, and with a maximum of 6 people working together in each group and, 6 group stations were installed to the reach the desired room capacity – each with an interactive whiteboard. In addition, an interactive whiteboard was installed in the teacher area/podium. Flexibility was paramount in the room design, and the placement of the tables made it easy to daisy-chain group stations when needed (e.g. during video conferences).

The first version of the digital learning labs was run as a pilot in autumn 2010. During this first term of use, several issues with the room setup were identified, and the room design was therefore revised during the summer of 2011. The revised setup was used as of autumn 2011 up to the present moment.

In subsequent sections, we will refer to both the pilot setup and revised setup, to highlight some of the design issues we encountered, and how these were rectified. We found that even minor changes to the room setup could greatly improve the functionality of the room.

2.1 Space and interior design

2.1.1 Pilot setup

Each group station was designed to have room for a minimum of 5 students – including enough table space for their own portable PCs; books; pen and paper, and lab equipment. In its original configuration, the digital learning labs used standard desks – in this pilot phase, we did not want to invest heavily in new tables, since the main focus of the pilot was to investigate the effect of student collaboration using interactive whiteboards – and so the tables were a secondary component.

The pilot setup of the learning labs is illustrated in Figure 1.
The pilot version of the learning labs consisted of only one room, measuring approximately 1100 cm x 600 cm x 240 cm. With six group stations and a maximum group size of 6 students, the pilot version could accommodate a total of 36 students. A wider room would have been preferable (the 600 cm width allowed little room between tables), but this was the only room available at the time.

Each table was equipped with power sockets for laptops, pads etc. These had the unfortunate effect of reducing table space for laptops, books etc., and the table legs made it difficult to move chairs around the table. The chairs were of standard type – lightweight, comfortable and they could be moved without generating noise.

The pilot setup did not have any kind of physical separation between group stations, and noise and distractions between groups did become an issue during the term of 2010.

2.1.2 Revised setup

After one year of usage, several more usage scenarios for the digital learning labs were identified, and the rooms were redesigned to accommodate four main scenarios:

- Using the interactive whiteboard as a common work surface for all students in the group. Every person in the group should be able to see it clearly, and it should be easy to walk up to the whiteboard and use it. There should be enough room between the table and the interactive whiteboard for two students writing on the board simultaneously.
- Normal meetings and group discussion/collaboration
- Video conferences – to this end, v-shaped conference tables were chosen, in order to maximize the viewable area for local participants, and also to give the remote party in the videoconference an unobscured view of all the participants
- Physical relocation of the tables, to accommodate larger groups or to turn tables 90 degrees to change the focus towards the teacher area. This involved the ability to connect two or more tables together.

In addition to changing the tables, connector boxes for connecting peripherals to the computer connected to the interactive whiteboard were installed in each table, as illustrated in Figure 2.

Figure 1: Pilot learning lab design, september 2010

Figure 2: Connector box for power, ethernet, VGA and USB
The connector box can be closed to lie flush with the table surface, which maximizes table space and avoids cluttering the table with power supplies and cables. The legs of the table are designed to allow people to move their chairs along the sides of the table without bumping into obstacles.

Since audio-visual interference between groups had been identified as an issue, a flexible rig with stage curtains was installed to reduce noise levels and also to accommodate more of the usage scenarios. By drawing the curtains, each group could remove distracting factors, which made it easier to focus on the common workspace – the table and the interactive whiteboard. Additionally, curtains provided visual shielding for groups during sessions in which privacy was an issue.

The revised design of the digital learning labs is illustrated in Figure 3.

![Figure 3: Revised version of the learning labs, autumn 2011](image)

In the revised setup, the capacity of the learning labs was nearly doubled by duplicating the setup in another room of almost identical dimensions (the new room had room for only five group stations because certain parts of the existing infrastructure could not be removed to make room for the interactive whiteboard), and so the revised version has a total capacity of 66 students with a group size of 6.

## 2.2 Sound and acoustics

### 2.2.1 Pilot setup

The pilot setup of the room didn’t include any modifications of the acoustical properties of the room, except curtains in front of the room windows (these were installed to reduce the amount of ambient light into the room, rather than to modify its acoustical properties)

### 2.2.2 Revised setup.

To control the acoustics in the room, a curtain rig was installed. The curtains were specially designed with extra folds (50 % fullness), to increase weight and hence the acoustic absorption. All the curtains were made from a heavy (600 g/m²), fireproof fabric called stage molton.

Even with the curtains drawn back (i.e. not acting as room dividers), they have a desirable effect on the reverberation of the room. In this position, the reverberation time is about 0.6 s, which is very good for normal lectures and other standard classroom activities. The curtains also help reduce the background noise level, further enhancing speech intelligibility. This makes it easier to tolerate the typical intermittent noises that are invariably generated by the students.

In the other scenarios the curtains act as visual and acoustic barriers. They create a visual and acoustic “group station environment” optimized for activities within the group or in communication with others through videoconference.

For video conference scenarios, the most important factor is good audio. The curtains create a closed space, with very good acoustics – which enhances both the sound picked up by the microphone (for the remote site), and the sound played back by the loudspeaker. The so called critical distance is not a problem within the closed space of the group station.

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1 Critical distance is the distance at which the reverberant sound field is equal in level to the direct sound from a sound source. The intelligibility of sound received from beyond the critical distance is greatly reduced.
While it’s not possible to acoustically insulate the group stations from each other, but the curtains help reduce it to a point where the speech Intelligibility is reduced to a level where one group cannot hear what the other is saying. This helps the students to keep focused on the activities in the group station.

Two common usage scenarios are illustrated in Figure 4: one with the curtains drawn back (open configuration), and one with the curtains closed and the tables relocated.

**Figure 4: Two common usage scenarios: curtains drawn back (left) and curtains closed and tables relocated (right)**

### 2.3 Lights and colours

#### 2.3.1 Pilot setup

Because video conferences were not a usage scenario in the pilot version of the learning labs, a minimum of resources was spent on optimizing the room colors. The room lighting was provided by standard light armatures, which tended to spill light onto the interactive whiteboard – thus diminishing the apparent brightness and contrast of the projected image.

#### 2.3.2 Revised setup

The room colours and lights were designed to better suit the different usage scenarios. The visual appearance of the room became a priority, and the curtain colours were picked to give a nice-looking background for video conferences. The earth hues of grey and blue of the curtains enhance the video quality of the transmitted image during video conferences, and the white, reflective ceiling diffuses light to create a uniform light coverage. The tables have a matte, cherry laminate surface to avoid reflection and blooming problems. The chair seats are made from dark fabric covering, and the legs are dark as well - chairs with bright metal finishes can interfere with camera lens brightness settings and auto-focusing controls.

The wooden frame on which the interactive whiteboard is mounted is also within the same colour space as the floor and the legs of the table.

The light armatures are suspended from the ceiling above the tables. The default light distribution is 60 % up into the ceiling, and 40 % down on the table. The upward and downward light intensity can be adjusted separately on all the armatures. The slightly warm colour temperature of the light was chosen to give a natural-coloured image in video conferences.
The difference in light intensity between the table surface and the interactive whiteboard should not exceed 10% to avoid eye strain (this could be an issue when students consult text books while simultaneously looking at the projected image), and this can be done by adjusting the overhead light.

2.4 Technological solutions

The main technical component of the group stations is the interactive whiteboard. For our purposes, the interactive whiteboard called SMART Board was chosen, with an ultra short-throw projector to avoid shadows on the projected image, and to keep light from shining into the eyes of the person writing on the board. The SMART Board was chosen because this type of board has been used extensively at HIST for several years with good results, and the teachers involved in the digital learning labs were already familiar with the SMART Board software.

The students mainly use the SMART Notebook software for making notes, drawings and sketches during discussions, and when answering exercises.

Another component is the SMART Sync Classroom suite, which is a monitoring tool used by the teacher to observe the activity on each group stations. The students can send instant messages to the teacher (e.g. to request assistance – the learning labs are located on two different floors, and the teacher may not be present in the room). The software, which is essentially a VNC client, allows the image on the teacher’s SMART Board to be projected on all the students’ boards, or vice versa.

The interactive whiteboards are connected to desktop PCs, where the students log in with their personal user profiles. Extension cables for keyboard, mouse and USB ports run from the table to the PC.

The connector boxes allow the students to connect their own equipment – e.g. to project a laptop image, or to connect laboratory equipment.

The digital labs have a high-speed wireless network for mobile devices such as pads, pods, smartphones etc. Using their own devices, students can access the internet, communicate through social media, participate in teacher-initiated quizzes and assessments etc.

3 METHODOLOGY

In the period autumn 2010-spring 2012, the digital learning labs have been used regularly in three main subject areas: physics, mathematics and language training. This focus of this article is the methodology used in the specific subject of physics, which was the first subject to use the digital learning labs in a systematic manner, and also the subject in which the students spent the greatest amount of time in the labs.

3.1 The physics classes

This article concentrates on the use of digital learning by two classes of mechanical engineering students, following a compulsory introductory physics course during their first term. Table 1 shows the physics classes who have been using the digital learning labs.

<table>
<thead>
<tr>
<th>Class</th>
<th>No. of students</th>
<th>Digital learning labs version</th>
<th>Time spent in the learning labs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Autumn 2010</td>
<td>93</td>
<td>Pilot setup</td>
<td>3 hours every three weeks</td>
</tr>
<tr>
<td>Autumn 2011</td>
<td>107</td>
<td>Revised setup</td>
<td>3 hours every week</td>
</tr>
</tbody>
</table>

Both years the students had two 90-minute ordinary lectures a week, and spent three hours per session in the learning labs. For 2010 term, the learning labs consisted of only one room with a capacity of only 30 students per week, and so the class was split into three groups to accommodate all the students. A rotation was organized in which every student spent every third group exercise in the learning labs (those who were not using the learning labs, worked in groups in normal meeting rooms without any digital tools whatsoever).
The students received extra credit for the group exercises – the average grade of all the exercises handed in during the term (about 10 in total) counted 20% towards the final grade. The remaining 80% of the grade was the result of a 4-hour written exam, which the students answered individually.

3.2 The curriculum

The introductory physics course for mechanical engineering students has 10 ECTS credits allocated to it, and is designed to give the students a broad, non-calculus introduction to classical physics. Subjects include kinematics; dynamics; rotational dynamics; thermodynamics and fluid mechanics.

3.3 The pedagogical approach

Before the learning labs were introduced, this particular physics course was taught by three 90-minute lectures a week. With the learning labs in place, the time spent on lectures was reduced to two 90-minute lectures a week and a three-hour session with the students in the learning labs.

In the lab, students would work in groups of 5-6 students, doing exercises in one of the following categories:

- “Traditional” text-based exercises to train basic computational skills in physics.
- Exercises which involved computer simulations (e.g. projectile motion).
- Video-based exercises, in which a physical phenomenon or laboratory experiment was filmed, and the students had to make inferences or calculations based on observations from the video (e.g. a video of a person standing on a set of scales in an elevator, showing how the apparent weight of the person shifts when the elevator is accelerating – and the students are tasked with calculating the acceleration of the elevator at various points in its movement).
- Open-ended, contextual exercises, where the students had to make their own assumptions and then perform calculations based on those assumptions, using a problem-solving strategy of their own choosing (e.g. estimating the distance covered by a track cyclist producing a given power output – here the students had to decide how to model air resistance, and also estimate the front area, drag coefficient etc. which affect the air drag).
- Open-ended lab experiments, in which the students were tasked with determining various quantities of some physical system (e.g. “Determine the moment of inertia of a bicycle wheel”). Being open-ended experiments, the students were free to decide which measurements should be done, and which calculations to perform in order to determine the quantities in question.

Some examples of the different types of exercises are shown in Figure 5.

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Computer simulation

Video-based exercise

Open-ended exercise

Stack the blocks in such a way so as to maximize the overhang.

The video shows a person standing on a set of scales inside an elevator. Use the video to determine the upward and downward acceleration of the elevator, respectively.

Estimate the number of helium balloons needed to lift a 20-kg child from the ground.

Figure 5: Examples of the different types of exercises given to the students during the physics course.
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The physics class of autumn 2011 had more of the video-based and open-ended exercises, and more lab experiments than the pilot class of 2010.

3.4 The students’ work in the digital learning labs

The students worked in groups of 5-6 on the exercises described in section 3.3. The teacher was present during these sessions – to observe how the students worked, and also to provide some guidance for students who struggled with the exercises. The teacher would not provide any direct answers to exercises, but would discuss with the students their problem-solving approach, and also provide feedback on the plausibility of their answers.

3.5 Digital learning lab evaluations

Both classes (2010 and 2011) answered end-of-term surveys to evaluate the use of the digital learning labs. The results of the 2010 survey gave very useful feedback for the redesign of the room the following summer:

- Noise: the original lab design did not have sound-absorbing curtains separating the group stations, and the students were complaining about distractioningly high noise levels in the learning labs.
- Room access: even though the students were supposed to be able to complete the exercises within the allocated 3-hour session, this was sometimes not possible. The students therefore requested room access outside the scheduled sessions (e.g. in the evenings).
- Exercise workload: the students felt that the workload on the first couple of exercises was too high, and failed to take into account the time for the students to get accustomed to the interactive whiteboard technology. It was therefore suggested to reduce the workload in the beginning to help ease the transition from “traditional” written exercises.
- Training: for the autumn term of 2010, the students were given a minimal amount of training in the use of the interactive whiteboard technology – under the assumption that the students would quickly acquire the necessary skills by themselves. The students reported that more thorough training in the use of the technology in the digital learning labs.

3.6 Logistical considerations in the digital learning labs

From the beginning, we wanted to achieve a smooth transition between lectures and work done in the learning labs. To this end, the students’ schedule was designed so that lectures were held early in the week, and work in the learning labs came later in the week. This schedule allowed the lecturer to give the students the necessary theoretical background before the students started working the exercises in the learning labs.

All exercises were submitted electronically using a learning management system (LMS). The exercises were handed in electronically by one member of the group, and upon grading the exercises, all members of the group received the same grade.

In addition to grading the exercises, thorough feedback was given to the group on every single exercise, highlighting problem areas and giving credit for exceptional performances (especially the open-ended exercises allowed for a variety of problem-solving approaches, and some groups put in huge efforts to answer these properly).

4 RESULTS

The students answered surveys to evaluate the digital learning labs at the end of the term, and these questionnaires related to both the technical aspects of the learning labs (the students could provide feedback on specific technical features which did not work well, or provide feature requests), as well as the teaching methodology which was used in the labs.

As indicated by ¡Error!No se encuentra el origen de la referencia., the students’ overall impression was that the learning labs worked well.
It is also evident from ¡Error!No se encuentra el origen de la referencia. that the class of 2011 was significantly more satisfied with the learning labs than the class of 2010. This was partly because the room setup was revised – doubling the room capacity meant that each student would spend three hours in the learning labs every week, while the previous class spent only every third week there. For the 2011 term, changes were also made to the methodology – in particular, the exercises were revised for 2011 to put a stronger emphasis on collaboration (e.g. by including more open-ended exercises and lab experiments).

When the students were asked about which aspect of the digital learning labs they see as the most important for their learning, they would highlight the importance of collaboration, as indicated by ¡Error!No se encuentra el origen de la referencia.. 54 % of the students reported the group aspect, while 36 % indicated that the main benefit was having an arena for discussing physics with fellow students.

A testament to the fact that the students enjoy working in the learning labs, is the observation that the labs have almost 100 % occupancy, also outside scheduled sessions – including evenings and weekends. The students use the learning labs at their own initiative for work on subjects outside physics.

5 CONCLUSION

Over a two-year development process, the digital learning labs have evolved from a pilot setup designed with collaborative learning in mind, to a more flexible setup which can accommodate a number of scenarios, including group-based collaborative work; normal lectures; video conferences and laboratory work.
The students report that the use of the digital learning labs in physics gave added value compared to more traditional methodology where exercises are worked and handed in on paper, and highlight the collaborative aspect – working together in groups on a common work area which can be seen and commented on by everybody in the group – as being the most important.

The methodology used for the physics classes did not strictly follow the dogma of collaborative learning or cooperative learning, but because the exercises done in the learning lab had a clear overall objective (increased student collaboration), an increased learning effect could be anticipated [9]. The research data available at the time of writing does not support a conclusion about the relative efficiency of the digital learning labs compared to group-based methodologies without interactive whiteboards, since no reference groups have been used so far. As of the autumn term 2012, an introductory mathematics course will follow the methodology outlined in this article, and this will be cross-references with classes following a more traditional methodology.

A variety of critical success factors have been identified the digital learning labs, in particular:

- Enough physical space to install conference tables and curtains between group stations
- Proper student training in the use of interactive whiteboard technology
- Continuity in the learning lab usage – each student should use it every week
- Open-ended exercises which promote student collaboration

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