Hybrid Data Communication Lab – a Case Study

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Abstract—Due to restrictions following the Covid-19 pandemic, major changes regarding teaching have been called for. Since students' presence in lab classrooms has been very restricted also physical labs have had to be transformed into e.g. simulations performed at home or via remote connections. After lifting of the restrictions, hybrid learning where both physical and simulated lab environment are combined have been introduced. This report describes such a case regarding a lab in data communication for electrical engineering students on bachelor level. The result shows added value to the learning outcome of the lab.

Index Terms—Hybrid learning, data communication, physical and simulated lab lessons.

I. Introduction

Restrictions due to the Covid-19 pandemic forced major reconstruction of courses. This included distance lecturing, but also a strive towards distance lab lessons. In some cases that called for solutions which allowed the students to remotely control lab equipment, in others a transfer to a simulated environment was a valid solution.

After the pandemic restrictions were lifted, it was possible to combine the simulated environment with the real life lab lesson. Thus, a blended or hybrid learning situation was possible to implement. This paper discusses the outcome of of such a hybrid lab.

The Data Communication lab is part of a mandatory basic communication systems course for students at third year of the electrical engineering program at Lund University, Faculty of Engineering. The lab is also given, with variations, in a parallel course for the Computer Science program.

The lab is developed with the objective to allow students to get acquainted with basic functions of the physical and data link layers of the Open Systems Interconnect (OSI) reference model. Another learning outcome of the lab is to read, understand, and implement a protocol reference document [1].

The student's task is to program one of the boards so that, given the protocol requirements, it can communicate with the other boards which are provided pre-programmed to the students. The lab is divided in two sessions with mandatory preparations for each. From the first part, students should learn how to go from a frame to bits to symbols to pulses and vice versa [2]. The second part [3] introduces addressing, Automatic Repeat reQuest (ARQ), and Cyclic Redundancy Check (CRC).

This paper presents a short literature study in Section II. The simulated environment is shortly discussed in Section III. Section IV gives a short description of the lab sessions procedures. In Section V, the accomplishment of the two labs and the didactic outcome is discussed. The report is summed up in Section VI.

II. Background

Several conference papers and articles concludes the same: a blended or hybrid learning is beneficial for the learning process.

Already 2001, Kennepohl compared two groups of students following a distance course [4]. One group did computer simulations and the other did not. The two groups did not differ in overall course performance, but the simulation group showed better performance in the practical laboratory work. In a study from 2013, Kennepohl finds that the combination of laboratory modes for distance chemistry students like virtual, remote or home-study laboratory lessons returns more meaningful student engagement and learning [5].

Gregory and Trapani concludes in a study that the impact on the nature of student preparation practices by pre-laboratory online resources in a blended learning environment is positive [6]. Also, hands-on laboratory lessons enhanced by simulations show advantages on student's learning [7]. Jaakola and Normi states in [8] that the combination of simulation and hands-on exercises renders better outcome than simulations or hand-on exercises alone.

In [9], Sanchez-López et al. compared the outcome between students who performed a hybrid chemistry lab course with students working in a virtual lab. The assessment showed that students with hybrid learning considered they were more active in practical work than what the virtual lab students did. The former group also performed better and showed a greater understanding of the course material.

Ohlsson et al. show in [10] that students express that a home lab was beneficial compared to not having the lab at all, but also that the home lab was less improving than an ordinary lab class. On the other hand, not having teacher support available all the time stimulates student's to try to solve problems with the lab on their own and only ask when really needed.

III. Lab Environment

The physical lab's infrastructure is Arduino Uno Boards [11] with shields made at the department of Electrical and Information Technology (EIT), see Figure 1.

The simulated environment is based on the Windows program UnoArduSim, developed and distributed as free-ware by Associate Professor S. Simmons at Queens university, Ontario, Canada [12]. The program includes a simulated Arduino Uno or Mega board, an Integrated Development Environment (IDE) with editor and compiler along with a multitude of simulated input/output (I/O) modules. The default main panel is shown in Figure 2. A real-time overview of used variables' content facilitates the debug process. An analyser pane allows for real time display of the state of each pin on the simulated board as shown in Figure 3.
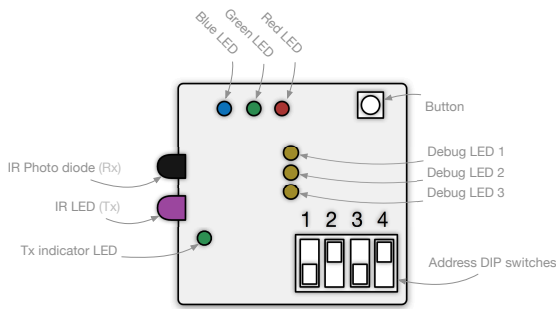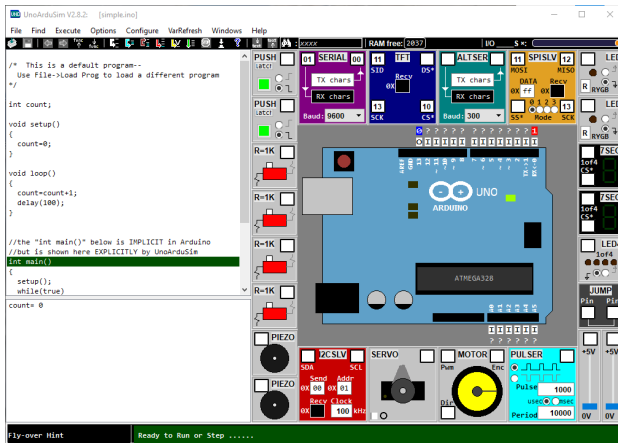
Figure 1. Shield layout

Figure 2. UnoArduSim's main panel.

Figure 3. UnoArduSim's analyser panel.

Figure 4. UnoArduSim with the labs shield modelled.

The lab specific shield (Figure 1) was modelled as shown in Figure 4. Other than Light Emitting Diodes (LEDs), push button and switch modules, the PROGIO module is essential for the use in this lab. This module is a fully programmable secondary Arduino Uno, that can communicate with the main board with up to four digital connections.

The lab's code library and Development Node skeleton has been adapted to the simulated environment. There are differences between the compilers in the Arduino IDE and the UnoArduSim IDE which has to be considered; in our case these caused only very few changes to the original code.

A problem, that exists in both lab infrastructures, is that the two predefined nodes, i.e. the Master Node and the Access Point, should not reveal part of their implementation to the students. Both the Master Node and the Access Point must of course have the full protocol implemented, and thus access to the code for these nodes include the solutions to fundamental parts of what students should produce. In the physical lab, the code for the Master Node and Access Point is only accessible for the lab Teaching Assistants (TAs). The code for the simulated Master Node and Access Point differs to such extent from what the students should produce and is thus not useful for copy-and-paste.

IV. HYBRID LAB SESSIONS PROCEDURES

The physical lab is split in two sessions. Both sessions are in turn split in preparations and practical work with examination b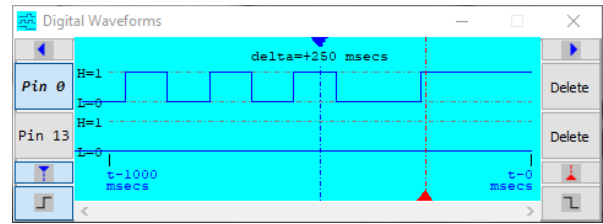y the TAs. 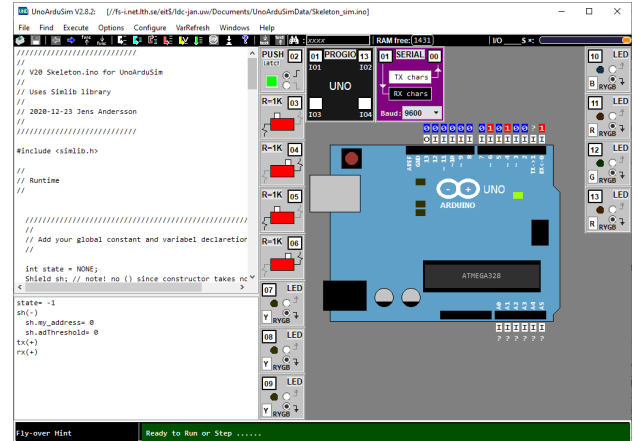The first session covers the physical link, i.e. forming pulses from symbols and symbols from data-bits. Frames, addressing, ARQ and error check, i.e. CRC are covered in the second session.

The preparation task for both lab sessions is an individual assignment. Written answers to questions and problems including code snippets are requested. The students submit their preparations and get feedback from the TAs a few days before the hands-on lab sessions.

The practical tasks are solved in groups of two, and students are assessed at the hands-on session. The simulated environment is accessible for the students from the start of the lab course, and thus code snippets can be tested. Even a fully functional program or sketch can be produced before the hands-on session. Students can download the simulation environment and Development Node skeleton to their own computers, or they can run the simulations on the departments lab workstations.

V. LAB ACCOMPLISHMENTS AND DIDACTIC OUTCOME

With the physical lab, the students have access to the lab equipment, i.e. the Arduino boards, only during the scheduled lab session. Since these are included in the examination, the demand and pressure on the students to be so well prepared that they can first get acquainted with the lab environment, test and verify their code, and finally being examined is high. One significant advantage with the simulated environment over the physical, is that the students have full access to the lab environment from day one of the course. They can thus both develop, test, and verify their code's functionality over a longer period and under lesser stress.

A main downside of the simulated environment is that the unreliable infra-red (IR) links between the nodes is in the simulated environment replaced by a fully reliable link. The need for functions that can cope with not reliable links can not be exemplified and the students implementation of such functionality can not be tested in the simulated environment.

A minor student survey was performed during the course 2022. Answers and remarks from 22 students out of 66 were received. The use of the simulated environment was optional and 14 students had used it. Those who used the simulated environment said it was supportive and useful. It helped to get the two hands-on sessions done in time. All 14 students recommended other students the use of the simulated environment. Comments from the non-users were that the environment was to complicated and not very intuitive or user-friendly. Other non-users said it was not demanded and also that it was not exactly the same as the hardware. The response rate is low and users are likely over-represented among the answers. Also, it can be assumed that the answers would be similar for other users and non-users.

The TAs report, in a comparison between the physical only lab and the hybrid lab, that the written preparations are somewhat similar. In the hybrid lab, more students are able to finish in time. The students are more prepared and with better ideas of what is expected of them. The coding and syntax is a bit less of a problem. Many students have actually fully completed the lab when arriving to the hands-on session. Students also seem less stressed during the lab session. There are some complaint and confusion about the slightly different compilers in the simulated and physical environments. Since the use of simulated environment is not mandatory, only ambitious and interested students used it, others tend to ignore its possibilities.

Another problem is that the lack of instant support led to students trying to solve problems on their own which was not always positive.

VI. Conclusions and final remarks

Distance teaching experiences and produced laboratory material, due to the Covid-19 restrictions, was used in a hybrid learning situation. The example discussed herein shows that a mixture of simulated and physical environment could be beneficial both for the students learning situation but also for reducing hands-on lab time.

The solution adds a free-ware application simulating Arduino boards which can be executed on student's own computers. This allows the students to have full access to a simulated lab environment from day one of the course, which is a positive side effect. Normally, the students meet the lab environment first at the lab session which also include examination, a fact which is stressful for the students. The experience of the simulated environment is close to that of the physical environment. But, available support has to be addressed.

Overall, the lab's learning outcomes were increased for those students who actively used the simulated environment. This was especially true for the practical part.

The remote and digital teaching will lead to changed teaching techniques. An educated guess is that a hybrid method will be used in the future, maybe more true regarding lectures and seminars, but the experiences drawn from this lab is that it can be true also for more physical activities.

References

[1] "Data Communication Lab: Reference Manual," 2022.

[2] "ETSF15 - Data communication Lab: Physical Layer," 2021.

[3] "ETSF15 - Data communication Lab: Link Layer," 2021.

[4] D. Kennepohl, "Using computer simulations to supplement teaching laboratories in chemistry for distance delivery," *The Journal of Distance Education / Revue de l'Éducation à Distance*, vol. Vol 16, No 2, 2001.

[5] D. K. Kennepohl, "Learning from blended chemistry laboratories," in *2013 IEEE Fifth International Conference on Technology for Education (t4e 2013)*, 2013, pp. 135–138.

[6] S.-J. Gregory and G. D. Trapani, "A blended learning approach to laboratory preparation," *International Journal of Innovation in Science and Mathematics Education (IJISME)*, vol. Vol. 20 No. 1, 2012.

[7] R. Wijayanti, K. H. Sugiyarto, and J. Ikhsan, "Effectiveness of using virtual chemistry laboratory integrated hybrid learning to students' learning achievement," *Journal of Physics: Conference Series*, vol. Volume 1156, 2019.

[8] T. Jaakkola and S. Nurmi, "Fostering elementary school students' understanding of simple electricity by combining simulation and laboratory activities," *Journal of Computer Assisted Learning*, vol. 24, no. 4, pp. 271–283, 2008. [Online]. Available: https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1365-2729.2007.00259.x

[9] A. L. Sánchez-López, L. M. Lozano-Sánchez, A. Parra-Córdova, J. Castañeda-Sedano, and J. I. Ek, "Implementation of hybrid chemistry labs as a learning strategy in post-covid times," in *2022 IEEE Global Engineering Education Conference (EDUCON)*, 2022, pp. 683–686.

[10] M. C. J. G. I. S. P. A. Pelle Ohlsson, Andreas Ehn, "Home labs – are they here to stay?" in *LTHs 11:e Pedagogiska Inspirationskonferens*, 2021. [Online]. Available: https://www.lth.se/fileadmin/cee/genombrottet/konferens2021/F3_Ohlsson_etal.pdf

[11] "Introduction to the arduino board," https://www.arduino.cc/en/Reference/Board, 2015, last visited 2023-01-09.

[12] S. Simmons, "UnoArduSim," https://www.sites.google.com/site/unoardusim/home, 2020, last visited 2022-12-12.