Remote Labs Didactics

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***Abstract*— This Work-in-Progress Innovate Practice Short Paper is concentrated around online teaching and learning and especially focused on the didactics in remote labs. In a remote lab, the lab equipment or instruments are geographically at another place than the student (and/or lecturer) himself. Learning will take place through the internet. Insights from online teaching and learning help to define what is needed in the special case of teaching and learning in remote labs. Feedback and interaction remain key factors for effective learning. Types of interaction in remote labs are: student-lecturer-, student-student-, student-content-, and student-interface interaction. These forms of interaction should be worked out when setting up a remote lab environment for students, taking online engagement into account. The purpose is to come with an overview of didactical methods for teaching- and learning in remote labs.**

Keywords*— *remote labs, online teaching and learning, didactics, higher education

I. INTRODUCTION

In these confusing and surrealistic times, where the fight against the COVID-19 virus dictates our behavior, higher (engineering) education is taking measures to cope with the new situation as well. Students and lecturers work from home, and all kinds of online education are implemented at high speed, to be able to serve the students as good as possible. Online classes, remote assessment, video colleges, team meetings in various platforms are just a few examples. One of the educational settings that cannot easily be replaced by an online alternative, is the work done in labs. However, there are possibilities, such as labs working with augmented reality (where real and virtual objects are combined, and with real time interaction), virtual reality (real time display of an accurate 3-D model of a system) and remote labs. Working with remote labs - a real lab in which the student and the equipment/instruments are physically apart - offers an opportunity to perform an experiment over the Internet [1], and as such, provides the students with the possibility to get lab experience at any time and from any place they prefer. In this short paper, the focus will be on the didactics in remote labs. To avoid confusion, since didactics can mean different things in different languages, by didactics is understood the what, the how and the why of teaching and learning: what should be taught and learned, how should it be taught and learned, and to what purpose or intention (why) should something be taught and learned [2]. First, insights in online teaching and learning will be discussed. After that, literature around remote labs in education is discussed and finally, teaching and learning in remote labs will be addressed.

II. ONLINE TEACHING AND LEARNING

A. Online Teaching

When online teaching, learning and the use of technology are viewed as a system of three components: the lecturer, the student and the content, the Digital Didactical Design (DDD)-framework can be used as a tool to structure the online teaching and learning processes [3]. DDD uses five elements for this structure: (i) teaching goals, (ii) learning activities, (iii) assessment, (iv) social relations, and (v) web-enabled technologies. These elements are equally important in face-to-face education as in distance teaching. In different educational settings, lecturers have to think about the goals they want to achieve, the learning activities they would like to address, the way by which they would like to know if they achieved their goals, the way they set up interaction and feedback, and which media to use. This way, the lecturer can set up and develop a learning experience for the students in an educational context. In online teaching, especially the fourth element needs attention. Social relations are not that obvious when sitting behind a screen. In a literature review [4], five different kinds of online engagement were revealed: emotional (commitment to learn), social (development of relationships), behavioral (development of skills), cognitive (development of deep learning) and collaborative (learning with others). A main focus on cognitive engagement seems obvious, but the five are all interconnected. To help students feeling less isolated and becoming part of a community, for example discussion fora could be set up that encourage social conversation and personal responses. Student engagement in higher education has a significant influence on student outcomes, including the successful completion of studies [4]. Others emphasize the importance of social presence in online learning communities and promote collaborative learning [5]. Furthermore, a distinction can be made between synchronous communication, having all participants interact at the same time, and asynchronous communication, where, for example, feedback and interaction are dealt with at a later stage. Watching recorded video's or replying to e-mails are examples of asynchronous communication. Element five, web-enabled technologies, also needs attention. If a lecturer decides to use technology, she/he needs not only to know how to use them, but should also be aware of the pedagogical strengths and weaknesses. Teaching in a digital age requires mastery of the systems the lecturer wants to use in her/his online teaching [6].

B. Online Learning

When focusing on the online learner, the five-stage model [7] is of use. The first step a student needs to do is setting up the system and getting motivated to start an online learning journey. After that, the online socialization needs to take place to create the basis of the online community. It is about sending and receiving messages and bridging the distance between cultural, social and learning environments. Stage three is about information exchange, with other students or with the lecturer. Feedback is crucial to gain insight in how to develop as an online learner. The fourth stage is about knowledge construction and completing the projects. The final stage concerns the development the student has gone through. She/he can apply the gained knowledge and skills in new settings. In all stages, the lecturer supports the student in going through the five stages.

III. REMOTE LABS

In higher engineering courses, there is a need to have practical experiences. The benefits of engineering laboratory practices are widely known and necessary for any person who seeks to understand the real-time performance beyond an ideal modelling [8]. Lab experiments allow students to learn to apply theoretical concepts to practical situations, as well as handling instruments, equipment and data. Remote labs provide an alternative and/or complementary way to develop knowledge and competences, being an online approach to laboratory learning. Remote labs are software and hardware environments which extend the laboratory concept into the cyber-physical world and provide students with the capability to:

- operate complex instrumentation at remote locations;
- control operations in real-time;
- access and document system configurations and setting;
- acquire and document measurements;
- mechanically handle, modify and access devices (e.g. 3D printing and robotic capabilities);
- securely access and operate the remote instrumentation.

These online resources offer new learning space(s) and have three main advantages: accessibility, availability, and safety. Remote labs can basically be operated 24/7 and students can get access to the learning space whenever they are ready for it, practicing at their own pace [9], repeating and adjusting as many times as they want to complete a certain lab task, fostering a deeper learning this way. Also, working with delicate materials that require many safety measures can be done safely from home. Another feature of working with remote labs is the cost aspect: there is no need to buy the same expensive equipment for every higher education institution.

Research and development around remote laboratories takes place in an international context, for example: the International Association of Online Engineering (IAOE), the Global Online Laboratory Consortium (GOLC) and the Experimentation and Laboratory-Oriented Studies Division of the ASEE. Relevant publications can be found in the International Journal of Online Engineering (iJOE) and in the proceedings of the International Conference on Remote Engineering and Virtual Instrumentation (REV), and the ICL-International Conference on Interactive Collaborative Learning (ICL) [10].

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IV. TEACHING AND LEARNING IN REMOTE LABS

In researches, educational benefits of remote labs are not often the main focus [11]. Mostly, the emphasis is on the technological and infrastructure side. However, thinking about didactics in online education seems even more important than in face-to-face education. Intervention researches focusing more on the improvement of instruction quality than on the technical tools, resulted in a higher amount of graduated students [12]. Instructional support is an important element, especially in web-based learning settings. Solving complex problem without instructional support can lead to ineffective learning. In remote labs, a (tele-)lecturer can communicate via mostly asynchronous communication tools with her/his students, playing a central role regarding instructional support [13]. Answering doubts via e-mail, making tutorial videos or documents, are examples of this kind of instructional support. Distance learners in remote labs can benefit from the knowledge and experiences of other users via chat fora, or e-mail, for example. This way, they can build a strong network of various experts, helping them in solving complex problems [14].

What can be learned from the general principles for online teaching and learning is the importance of building a community of learners, where interaction and feedback have to be put central, especially or even more in remote labs.

The four types of interaction that can be found in working in remote labs are: (i) student-lecturer interaction (two-way dialogue), (ii) student-student interaction (group work), (iii) student-interface interaction (getting access and participate) and (iv) student-content interaction (getting intellectual information from the instructional media) [14]. For each of these interactions, didactical methods need to be thought of and implemented. For (i) is already mentioned: use of e-mail and online tutorials. Added can be: online consultation hours, online debates with invited guest speakers and organizing digital working visits. A pedagogy of care should be put central while thinking of student-lecturer interaction[15] and, as such, building a community of leaners. For (ii) can be added, next to mentioned chat fora: peer-to-peer feedback, peer assessment and group work. Student-content interaction (iii) asks for dynamic assignments, clearly defined goals and assessment designed for the web. Finally, student-interface interaction (iv) is about user friendliness and an easy use, which could be reached by offering clear manuals and online tutorials as well as synchronous guidance when using the system (see also table 1). The overview of didactical methods in the different interactions will be complemented in the near future.

TABLE 1. Overview of didactical methods in remote labs

	Interactions in remote labs			
	Student-lecturer	*Student-student*	*Student-content*	*Student-interface*

synchronous	consultation hours	chat fora; group work	not applicable	guidance
asyn-chronous	e-mail; online tutorials; expert online classes; online debates; digital working visits	peer-to-peer feedback; peer assessment	dynamic assignments; clearly defined goals; assessment	online manuals; online tutorials

An example of a remote lab can be given from the Technical University in Eindhoven, Netherlands [16], where students in the Master Systems and Control are asked to design and implement remotely control strategies for three water tanks (see Fig.1).

Fig.1 Water tanks in remote lab-setting. Photo: Bart van Overbeeke

The course is set up as an open problem-course to align with Challenge-based Learning. The students work with two pumps and are able to open or close five different valves, while they get real-time information about the water levels via camera's and other sensors (student-content interaction). Students need to sign in via a booking system. When something goes wrong, the system sends a warning to an administrator. An instruction video about how to use the system has been made for the users (student-interface interaction). Student groups (student-student interaction) work independently on the water tanks in the remote lab setting, but can ask questions and get answers via e-mail. The progress of each group has been monitored by biweekly meetings and by feedback on the interim reports the students had to deliver (student-lecturer interaction).
Also Bachelor students Chemical Engineering and Chemistry use the remote lab, dealing with one water tank, one pump and one valve.
More research will be conducted to find out which concrete steps need to be taken to work effectively in the educational setting of remote labs. The end goal will be to come with an overview of didactical methods, to be used in the setting of remote labs and to validate two of these methods in practice.

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REFERENCES

[1] Lima, N., Viegas, C. & Garcia-Penalvo (2019). Different didactical approaches using a remote lab: identification of impact factors. *Revista Ibero-Americana de Technologias del Aprendizaje*, Vol. 14. Nr. 3, pp. 76-86

[2] Gundem, B. (2000). Understanding European didactics. In: *Routledge International Companion to Education*, Ben-Peretz, M., Brown, S. & Moon, B. (Eds.). London: Routledge

[3] Jahnke, I., Bergstrom, P., Marell-Ollson, E., Hall, L. & Kumar, S. (2017). Digital Didactical Design as research framework: iPad integration in Nordic schools. Computers & Education, Vol. 113. Doi: htpp://dx.doi.org/10.1016/j.compedu.2017.05.006

[4] Redmond, P., Heffernan, A., Abawi, L., Brown, A., & Henderson, R. (2018). An online engagement framework for higher education. *Online Learning,* 22(1), 183-204. doi:10.24059/olj.v22i1.1175

[5] Kreijns, K. (2020). Online collaborative learning and social presence. www.ou.nl.Doi: https://www.ou.nl/documents/40554/1186340/Oratieboekje_Karel_Kreijns_web_20200131.pdf/f94f3db1-0776-7ddf-e946-aefd9dee157e?t=1582207018806

[6] Bates, A.W. (2019*). Teaching in a digital age- second edition*. Vancouver, B.C.: Tony Bates Associates Ltd. Retrieved from https://pressbooks.bccampus.ca/teachinginadigitalagev2/

[7] Salmon, G., Nie, M. & Edirisingha, P. (2010). Developing a five-stage model of learning in "Second Life". *Educational Research*, 52(2), 169-182. doi: 10.1080/00131881.2010.482744

[8] Garcia-Loro, F., Sancristobal, E., Alves, G., Garcia-Zubia, J. & and Castro, M. (2016). New experiences and strategies in remote laboratories and apps for electronics: Proposal for a special session. *International Conference on Remote Engineering and Virtual Instrumentation (REV)*, Madrid, pp. 3-3

[9] Torre, L. de la., Sánchez, J.P. & Dormido, S. (2016). What can remote labs do for you. *Physics Today 69*(4), 48. Doi: 10.1063/PT.3.3139 View online: http://dx.doi.org/10.1063/PT.3.3139

[10] May, D. (2020). Cross reality Spaces in Engineering Education. *International Journal of Online and Biomedical Engineering*, Vol. 16(03). Doi: https://doi.org/10.399/ihoev16i03.12849

[11] Post, S., Guo, P., Saab, N., & Admiraal, W. (2019). Effects of remote labs on cognitive, behavioral, and affective learning outcomes in higher education. *Computers & Education*, Vol. 140. Doi: https://doi,org/10.1016/j.compedu.2019.103596

[12] Delnoij, L., Dirkx, K., Janssen, J. & Martens, R. (2020). Predicting and resolving non-completion in higher (online) education – a literature review. *Education Research review*, Vol 29. Doi: https://doi.org/10.1016/j.edurev.2020.100313

[13] Odeh, S. & Ketaneh, E. (2012). E-collaborative Remote Engineering Labs. *Proceedings of the 2012 IEEE Global Engineering Education Conference (EDUCON),* Marrakech, pp.1-10. Doi**:** 10.1109/EDUCON.2012.6201126

[14] Cormier, D. (2008). Rhizomatic Education: Community as Curriculum. *Innovate: Journal of Online Education* 4(2), Retrieved June 17, 2020 from https://www.learntechlib.org/p/104239/.

[15] Cormier, D. (2020). Daves's Educational Blog. Move to Online Learning: 12 key ideas, 17 May, 2020., Retrieved June 17, 2020 from http://davecormier.com/edblog/

[16] Jeltes. T. (2020). Practical classes from home thanks to Remote Labs, retrieved June 17th. 2020 from: https://www.cursor.tue.nl/en/news/2020/april/week-3/practical-classes-from-home-thanks-to-remote-labs/