Online laboratories and Cross-Reality in engineering education

COVID-19 has compelled educators to rapidly transition to online learning methods. This shift is particularly challenging for instructors whose courses involve hands-on laboratory instruction. In his research, Dr Dominik May, an Assistant Professor in the Engineering Education Transformations Institute at the University of Georgia, has been focusing on online laboratories and Cross-Reality learning spaces in engineering education for over a decade. Collaborating with researchers from the international community of engineering education research, Dr May has been involved in the digital instructional design of and respective educational research on courses for mechanical, electrical, biological, civil and computer engineers. His work provides an environment for collaborative engineering lab work for students irrespective of their physical location.

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The COVID-19 pandemic has compelled educators to hastily move to online instruction methods. While this shift is difficult for any subject, it is particularly challenging for those instructors whose courses involve hands-on laboratory instruction. This occurs in many STEM courses.

Research being carried out by Dr Dominik May, an Assistant Professor in the Engineering Education Transformations Institute at the University of Georgia, focuses on online laboratories and Cross-Reality learning spaces in engineering education. Dr May explains that he uses Cross-Reality learning spaces and labs as a descriptive umbrella term that covers all online laboratory solutions that use remote technology, augmented reality, virtual reality, and mixed reality.

KEY AREAS

Dr May's research focuses on three key areas that are in line with the overall trend of digitalisation in higher education. Firstly, he explores the integration of different online laboratory solutions with virtual experimentation activities that form part of the engineering curriculum, and investigates how they promote student engagement and student learning as well as improve their overall learning experience.

Secondly, he examines the assessment and evaluation of virtual experimentation activities aimed at improving the students' learning experience in Cross-Reality learning spaces, specifically during online laboratory-based instruction.

Thirdly, he investigates virtual experimentation activities designed to develop a fundamental understanding of cognitive and affective factors that influence the students' learning experience in Cross-Reality learning spaces, again particularly during online laboratory-based instruction.

Dr May believes that "face-to-face instruction and online instruction should never be seen as 'either-or' things, but it is important to examine, define, and combine the strengths of both worlds for the overall learning experience". His studies and work from other researchers in the field have shown that hands-on experimentation activities often focus on developing knowledge and procedural skills rather than the development of competencies to solve workplace problems. Furthermore, they require and promote different skills and competencies when compared with virtual experimentation activities. Both hands-on and virtual experimentation learning activities, however, can be combined according to their individual strengths and intended learning outcomes for a particular lab activity. Moreover, they can be tailored to the preferences or needs of the individual student, as well as the school's infrastructure and resources.

LABORATORIES AS A TEACHING AND LEARNING ENVIRONMENT

Dr May describes how the use of laboratories as a teaching and learning environment has been an essential part of science and engineering education at universities since the very beginning of higher education in engineering. Laboratories have a crucial role in both research-oriented and application-based study programs. He notes that to exploit the full potential of laboratories as a teaching and learning location, however, there must be a specific competence-oriented approach to learning in laboratories if the mere reproduction of specialist knowledge and skills is to be avoided. While research-based learning is the central paradigm of laboratory teaching, genuine competence development is essential to promote students' employability in science and industry.

CROSS-REALITY

Online or Cross-Reality laboratories encompass all types of digitally or online-supported teaching-learning laboratories. Cross-Reality labs employ emerging technologies, including augmented reality, virtual reality, and mixed or merged reality. Augmented reality labs can involve, for example, experimental setups that use augmented reality to display real-time data such as temperature or pressure directly on the test device. Cross-Reality technologies involve 3D models and simulations using physical, virtual, and immersive platforms and offer particular innovation potential for engineering education. Dr May's research consists in comparing real, remotely accessible and virtual instrumentation, specifically in the context of STEM education, and examining their impact on learning and communication practices and sociotechnical issues.

THE EAGER PROJECT

One of Dr May's foremost engineering education research projects is 'EAGER: Investigating the rapid transition from face-to-face to exclusively online engineering laboratory classes in an Electrical and Computer Engineering program', which is funded by the US National Science Foundation (award #2032802). This project examines the impact of using only online laboratory modules in an engineering laboratory course beyond COVID-19. Current work involves exploring the rapid switch from face-to-face experimentation to online laboratories from three different perspectives: the perspective of students taking Electrical Engineering and Computer Systems Engineering courses, the perspective of faculty teaching such courses and being in the role to adapt the own teaching habits, and the user experience perspective describing how both students and faculty experience the online environment. Bringing all three perspectives together is crucial to improve the instructional design in technology-enhanced lab-based engineering education.

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Cross-Reality labs employ remote, augmented, virtual, or mixed reality technologies to support online learning.

LEARNING COMPATIBILITY

Student interviews revealed several benefits of in-person labs. These included participating in the campus experience, feeling more hands-on as they were immersed in the lab environment, and getting more practice with the equipment. On the other hand, the students found that the online labs meant that they spent less time commuting and were able to work at their own pace and with respect to their own learning needs. Online labs also prepared them for future digital working environments, including working from home. They commented that working from home also allowed personal health safety during the pandemic. Some students found that using online labs exceeded their expectations as it was compatible with their circumstances and their growth in learning.

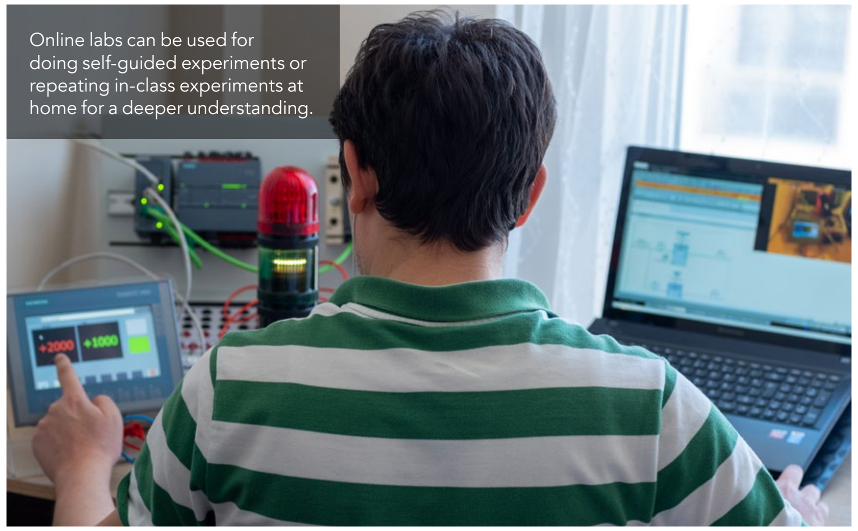
> **Hands-on experimentation activities often focus on developing knowledge and procedural skills, rather than the development of competencies to solve workplace problems.**

QUESTION AND INQUIRY

In online laboratory contexts, students were concerned as to how they would communicate with their professors or lab partners, particularly when they needed help. Clear communication and verbal instruction tend to happen naturally in face-to-face lab courses but require more deliberate planning during online instruction. Online students were more likely to access support if they knew that they could get help via Zoom calls or structured time to ask questions. Other comments from faculty and students revealed that online communication led to a more deliberate discussion, as the students needed to think about and properly formulate the question. Moreso, without the time constraints sometimes present in face-to-face lab courses, faculty had more time to think about their response.

PLANNING AND COORDINATION

To execute the lab successfully, students had to ensure that the equipment worked so that they could complete tasks properly and in the allocated time. They found that it was imperative



Online labs can be used for doing self-guided experiments or repeating in-class experiments at home for a deeper understanding.

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to remain organised and keep to the course schedule, which is more demanding in online settings compared to face-to-face settings.

Dr May explains that for online lab courses to offer a comparable educational experience that in-person instruction affords, the same educational and curricular value of laboratories must be maintained while taking advantage of the benefits offered by online education and online experimentation tools. As part of the project, he is carrying out a similar study from the instructors' perspective to determine how they deal with the rapid transition to exclusively online-based laboratory modules in engineering courses, and whether they resist or embrace these educational technologies.

The landscape of lab learning changed with the sudden transition from physical labs to online labs.

AN ONLINE REMOTE LAB STUDY WITH LABSLAND® AND ZOOM

Dr May has also been involved in a comparative study of an online remote lab using Zoom during COVID-19. The landscape of lab learning changed with the sudden transition from physical labs to online labs. This study involved using the remotely accessible version of a real electrical circuit lab environment for a class of 38 students during the 2020 spring semester.

The research team collaborated with the remote laboratory platform and company LabsLand®, used their VISIR (Virtual Instrument Systems in Reality) circuits remote lab module together with the video conferencing platform Zoom, and examined the students' perception and academic performance in the online lab settings in comparison with their previous experience of the physical labs. LabsLand® is a long-standing partner in Dr May's research and offers a platform with many online remote lab applications for several fields in STEM education.

FINDINGS

Analysing the results revealed that online labs successfully cultivated teaching and learning conditions reminiscent of a physical lab environment in an online setting. The online labs can be used for several purposes in engineering courses, e.g., for preparing face-to-face lab sessions online from home, doing own and self-guided experiments beyond the course curriculum, or repeating experiments after a live session or in advance of an assessment. The researchers also uncovered several challenges of online labs and suggest measures to address them. For example, students can find the online lab interfaces unintuitive.

The researchers advise instructors to study the interface's quirks and be prepared to spend a significant amount of time helping students deal with them. Compared with physical labs, online labs require more formal, intentional means of student collaboration. At the beginning of the course, instructors are advised to discuss what effective real-world teamwork looks like, together with the roles involved, as this can help students build teamwork skills. Students need access to their instructors for help with the lab activities and interface. Online labs should be structured to maximise students' ability to receive help from the instructional team. Following these guidelines can provide an environment for collaborative engineering lab work for students irrespective of their physical location. However, fostering social interaction and collaboration in online lab environments remains challenging due to still existing technical constrains. It is of vital importance for future educational development and research in this field to include social interaction in online labs to avoid loosing this very important component of the overall learning experience.

INTERNATIONAL COLLABORATION

Dr May is collaborating with colleagues within the University of Georgia as well as researchers from the international community of engineering education research, such as the International Association of Online Engineering and the American Society for Engineering Education. He has been involved in the digital instructional design of courses for electrical, biological, civil and computer engineers. Moreover, his work has led to the creation of the Engineering Education Transformation Institute's (EETI) Innovative Teaching Lab Group at the University of Georgia.

THE FUTURE OF ENGINEERING EDUCATION

Dr May's research addresses a critical requirement that has been exemplified during the COVID-19 global health crisis with the rapid transition to online learning. Nonetheless, looking beyond this crucial application, Cross-Reality learning spaces are a promising aspect of the future of engineering education, and respective educational research is vital to actively shape this future.

Behind the Research

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Research Objectives

Dr Dominik May focuses on online laboratories and Cross-Reality learning spaces in engineering education.

References

- May, D., Morkos, B., Jackson, A., Hunsu, N., Ingalls, A., & Beyette Jr., F. R. (under review). Rapid Transition of Traditionally Hands-On Labs to Online Instruction in Engineering Courses. *European Journal of Engineering Education.*
- Terkowsky, C., May, D., & Frye, S. (2020). Forschendes Lernen im Labor: Labordidaktische Ansätze zwischen Hands-on und Cross-Reality. In C. Terkowsky, D. May, S. Frye, T. Haertel, T. Ortelt, S. Heix, & K. Lensing (Eds.), *Labore in der Hochschullehre - Didaktik*, Digitalisierung, Organisation, 13-34. Bielefeld: wbv Publikation. (translated document)
- May, D. (2020). Wie Cross Reality die Hochschullehre verändern kann und wird. *Hochschulforum Digitalisierung (HFD)* online blog, 2020. Available at: https://hochschulforumdigitalisierung.de/de/blog/wie-cross-reality-die-hochschullehre-veraendern-kann-und-wird (translated document)
- May, D. (2020). Cross Reality Spaces in Engineering Education–Online Laboratories for Supporting International Student Collaboration in Merging Realities. *International Journal of Online and Biomedical Engineering*, 16(03), 4-26.
- Devine, R. P., & May, D. (2020). Effect of a Simulated Laboratory Intervention on Biological Engineering Student Motivation A Case Study. Paper presented at the International Conference on Remote Engineering and Virtual Instrumentation (REV) "Cross Reality and Data Science in Engineering", Athens, Georgia, USA.
- Devine R., May D. (2021). Work in Progress: Pilot Study for the Effect of a Simulated Laboratories on the Motivation of Biological Engineering Students. In: Auer M., May D. (eds) *Cross Reality and Data Science in Engineering. REV 2020. Advances in Intelligent Systems and Computing*, Springer, Cham. 1231, 429-436. Available at: https://doi.org/10.1007/978-3-030-52575-0_35 [Accessed 5th August 2021].
- Al Weshah A., Alamad R., May D. (2021). Work-in-Progress: Using Augmented Reality Mobile App to Improve Student's Skills in Using Breadboard in an Introduction to Electrical Engineering Course. In: Auer M., May D. (eds) *Cross Reality and Data Science in Engineering. REV 2020. Advances in Intelligent Systems and Computing*, Springer, Cham. 1231, 313-319. Available at: https://doi.org/10.1007/978-3-030-52575-0_25 [Accessed 5th August 2021].
- Li, R., Morelock, J. R., & May, D. (2020). A Comparative Study of An Online Lab Using Labsland and Zoom during COVID-19. *Advances in Engineering Education*, 8(4), 1-10. Available at: https://advances.asee.org/a-comparative-study-of-an-online-lab-using-labsland-and-zoom-during-covid-19/ [Accessed 5th August 2021].
- Terkowsky, C., Frye, S., & May, D. (2019). Online engineering education for manufacturing technology: Is a remote experiment a suitable tool to teach competences for "Working 4.0"? *European Journal of Education*, 54(4), 577-590.
- Pokoo-Aikins, G. A., Hunsu, N., & May, D. (2019). Development of a Remote Laboratory Diffusion Experiment Module for an Enhanced Laboratory Experience. *2019 IEEE Frontiers in Education Conference (FIE)*, 1-5.

Detail

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Bio
Dr May is an Assistant Professor in the Engineering Education Transformations Institute. His primary research focus lies on the development, introduction, practical use, and educational value of online laboratories and Cross-Reality learning spaces in engineering instruction. In his work, he focuses on developing broader educational strategies for the design and use of virtual engineering equipment, putting these into practice and providing the evidence base for further development efforts. Dr May is President of the International Association of Online Engineering (IAOE), serves as Editor-in-Chief for the International Journal of Emerging Technologies in Learning (iJET), and works as guest editor for special issues of international journals in education.

Funding
- German Federal Ministry of Education and Research
- American National Science Foundation

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- LabsLand®: Pablo Orduña (Co-founder & CEO, USA)
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Personal Response

What is the most important piece of advice that you would give to instructors using Cross-Reality learning spaces?

"My advice to instructors would be threefold: Embrace the opportunities the new technologies offer to your teaching and the classroom with an open mind. This might require stepping outside of your current pathways, but it will be absolutely rewarding. Secondly, introduce new approaches and technologies with respect to the course goals and the intended learning outcomes. Don't use online labs as an end in itself, but only if they help you reach your goals. And finally, maybe the most important one, be patient with the technology, the students, and yourself. New approaches might not work at first but will improve over time, which is normal. However, students are typically very patient as long as you are transparent about your goals, your strategies and even potential failures."

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