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Electronic Engineering Labs during Pandemic Restrictions – What Ireland did next

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Abstract– This paper investigates the shift in experiential education laboratories for electronic, electrical, and computer engineering courses in Ireland, driven by the COVID-19 pandemic. The pandemic forced higher education institutions to adapt their electronic laboratory sessions to a remote delivery model. This study categorizes and evaluates the different approaches taken by Irish higher education institutes (HEIs) to implement remote engineering laboratories. Using survey data, user feedback, and firsthand reports from 33 participants across 12 HEIs, the paper examines the effectiveness of these remote lab methods. The analysis identified five distinct remote laboratory delivery methods, with learning simulations and remote hardware lab kits being the most commonly employed. Although remote hardware lab kits were favored for their perceived effectiveness in replicating hands-on experiences, they posed significant challenges, including increased administrative workload, preparation, implementation, and management overheads. In contrast, simulated lab solutions, though less resource-intensive, did not fully capture the hands-on learning experience. This study highlights the complex challenges faced by Irish HEIs in maintaining effective experiential education in electronic engineering labs during the pandemic, shedding light on the advantages and limitations of remote delivery models and their implications for future educational practices in engineering disciplines.

Keywords-- Electronics & Computer Engineering, Teaching, Laboratory, Remote Teaching, Engineering Education.

I. Introduction

The COVID-19 pandemic acted as a global stress test for higher education, compelling institutions to transition from traditional in-person didactic teaching to remote learning with unprecedented speed. Nowhere was this disruption more acutely felt than in engineering education, and in particular in the area of electronic engineering. Here, laboratory-based, experiential learning traditionally plays a critical role in developing practical student competencies such as circuit assembly, instrumentation, and systems analysis. While previous research has explored isolated tools and remote strategies in STEM education, few studies have taken a holistic, comparative perspective on how these methods performed in real-world academic settings during a crisis such as the Covid-19 pandemic.

This paper introduces such a novel perspective by systematically examining and comparing how lecturers in Irish Higher Education Institutions (HEIs) adapted their lab-based teaching practices for electronic engineering during the Covid-19 pandemic. Drawing from a national survey of academic staff across multiple institutions, the study captures the breadth and diversity of pedagogical innovations implemented under emergency conditions. Rather than focusing on a single tool or approach, this research identifies five distinct methods used to deliver remote experiential education: learning simulations, remote lab kits, electronic lab notebooks (e-books), portfolios/formative assessment strategies, and Problem-Based Learning (PBL).

What sets this study apart is its focus on the comparative value and implementation dynamics of each method, rather than simply documenting their existence. The analysis explores not only the technical feasibility of each solution but also its pedagogical effectiveness, logistical demands, and perceived value from different perspectives. By contrasting these approaches side by side, the paper provides a nuanced understanding of which strategies offer scalable, sustainable potential beyond the pandemic — and under what conditions they are most effective.

Furthermore, the study's national scope offers an integrated view of engineering education responses within a cohesive educational system, making the findings especially relevant for informing post-pandemic curriculum design, technology integration, and pedagogical planning in both local and international contexts. The differential value of this work lies in its ability to bridge theory and practice by offering evidence-based guidance on how to effectively deliver experiential engineering education at a distance—not just during a crisis, but as part of a reimagined hybrid learning ecosystem.

II. Literature Review

In electronics and computer education, experiential education is traditionally implemented using face-to-face laboratory sessions, emphasizing learning through direct experience and reflection, promoting active student engagement and deeper learning experiences. Five approaches are considered here - Learning Simulations, Remote/Virtual Lab Implementations, Electronic Lab Notebooks/E-Books, Portfolios/Formative Assessments and Problem-Based Learning.

A. Learning Simulations

A learning simulation is any software program or tool that simulates the physical environment used in the laboratory setting for the students on their laptops or home computers. Recognized advantages include the fact that students can design and create virtual circuits, take measurements and log data from simulated circuits instead of physical ones, record results and write reports based on the experiments conducted in these learning simulations. [3] considered a classroom-based, simulation-centric approach to microelectronics education - incorporating simulation tools (e.g. SPICE) into the classroom to enhance student understanding of core concepts. Results showed substantial benefits for students using this methodology and positive responses to the active learning.

In Iran, [4] presents a web based interactive learning simulation designed and implemented to teach power electronics at undergraduate level in Shahrood University of Technology. [5] used simulation software packages to improve student understanding and learning in analog electronic technology - how it helps to augment understanding and minimize the difficulties of classroom teaching of the topic. The use of such software, the authors argue, helps to improve students' interest in learning, helping to cultivate the students' ability and innovation.

B. Remote & Virtual Lab Implementations

Remote/virtual labs involve some hardware aspect, e.g. a central lab setup that students can remotely log in to use or "take-home" lab hardware kits they can use to conduct labs remotely. The central lab approach uses remote connectivity to access equipment for running experiments, gathering data and collecting results – however, access is usually limited due to the need to share the hardware. The hardware kits approach uses the remote connectivity to run the labs on this hardware. This approach means more access to the experimental setup for the students; however, the capability of the experimental hardware is usually quite limited.

[6] reviews some of the developments and trends leading to these solutions for remote and virtual laboratory technologies and application for engineering education, focusing on the different kinds of technological characteristics. Complementing this, [7] give an updated overview of the virtual and remote laboratory system, considering some of the characteristics and relative advantages of each system type. [8] looks at a series of remote experiments in Industrial Electronics at the Faculty of Engineering of Porto University (FEUP), with observations on their pedagogical effectiveness. [9] describes a remote laboratory setup being used in a Higher Education Institution in Brazil across two different courses over three consecutive semesters, presenting topics covering electric and electronic principles to 471 students.

[10] considers some of the take-home kits for control and system engineering courses, presenting three distinct solutions and discussing the specifics of each implementation, main challenges to their usage and student usage across modules at the University of Sheffield. [11] presents a take-home laboratory kit for traditional control engineering laboratories - a low budget take-home control laboratory based on a simple thermal system that is safe and portable. [12] discuss another laboratory kit for the Department of Automation Engineering, ATEI of Thessaloniki, Greece - designed to serve the needs of undergraduate and postgraduate control education in several relevant courses. [13] presents findings from a case study conducted before/during the Covid-19 pandemic response at an Irish University, which illustrates the functionality of a typical "take home" low-cost platform. They report on the experiences of an engineering cohort who have encountered the different approaches to delivering practical learning through traditional laboratory and online settings.

C. Electronic Lab Notebooks & E-Books

Electronic lab notebooks (ELNs) are computer programs designed to replace paper lab books, providing an electronic platform to log research, experiments and procedures performed in a laboratory setting. "Smart" E-Books (or electronic books) are now more interactive than ever, allowing students to complete readings, take quizzes and finish assignments through the e-book interface. [14] look at using a robotics e-book to implement effective distance delivery of the laboratory experience for electronics students at Universities in Vancouver and Chicago. [15] consider the use of ELNs for laboratory classes, finding they improve pedagogy and learning outcomes of the lab course over traditional methods. [16] describe research into teaching material to help facilitate the learning process including visuals, audio-visual and interactive multimedia teaching material. Identified advantages of e-book(s) included the ability to deliver effective and efficient learning using such technology. [17] investigates the effectiveness of e-books as learning technological course tools and assesses student teachers' perceptions of the usefulness of e-books for their course learning. Teachers had a significantly more positive attitude towards the usefulness of the interactive e-book version for content learning as opposed to the other versions and reported more advantages and fewer disadvantages for the interactive version.

D. Portfolios & Formative Assessments

An electronic portfolio (e-portfolio) is a purposeful collection of sample student work, labs, demonstrations and other learning "artefacts" that highlight the learning progression, achievement and accomplishments of the student on a module/course. They allow students to realize the same learning outcomes using a more scaffolded and personalized approach.

[18] considers formative assessments in a laboratory pedagogy mixing the creation and maintenance of student portfolios with formative electronic laboratory assessments (ELAs) to deliver electronic engineering lab content. [19] describes the "Electronic Lab Assessments with Tutoring Enhanced Delivery (ELATED)" system, comprising a laboratory pedagogy incorporating both creative portfolios and online formative assessments in its design. The authors found advantages in student portfolios increasing the students' attention toward creativity, generating significant improvement

in student attitudes toward both their own texts and their approach to the writing and revision process for laboratory reports. Such authentic, performance-based assessment methods assisted the students by incrementally improving their analytical thinking and composition skills [20]. [21] discusses a customizable e-portfolio that allows sharing different parts of the e-portfolio across courses/disciplines which was developed at the Shiraz University of Medical Sciences (SUMS). The "Mahara" e-portfolio [22] describes an online/distance education solution based on student's Personal Learning Environments.

E. Problem-Based Learning (PBL)

PBL enables engineering labs to be redesigned as projects that students work on over an extended period, engaging them in solving real-world problem(s) or answering complex question(s) akin to the series of traditional laboratory sessions in many engineering disciplines. [23] considers a worked e-portfolio approach to improving the teaching/learning and evaluation processes in project-based learning environments, by designing and teaching a practical, project-based software engineering course supported by a Moodle-based e-portfolio. [24] describes using a PBL approach for teaching wind energy conversion systems for electricity generation at an Electrical and Electronic Master's degree level. [25] present a PBL approach to teaching basic concepts of electronics to undergraduate students of business and information engineering. Advantages included students developing skills in electronic circuit design, problem solving and teamwork; motivating the students and allowing them to experience and discover the link between physics, technology and engineering.

This literature review has considered five alternatives to the traditional electronics laboratory delivery method. Simulation-based approaches allow students to actively engage in hands-on experimentation within a virtual environment, promoting practical application of theoretical knowledge. Remote labs extend experiential learning beyond physical constraints, offering students real-world scenarios to enhance their problem-solving abilities and professional skills. The use of (relatively new) approaches such as e-Notebooks and Portfolios facilitate reflective practices and knowledge integration, fostering metacognitive development and active participation in learning processes. Collectively, these methods underscore the pivotal role of experiential education in augmenting the effectiveness and quality of online engineering education.

III. METHODOLOGY

This study employed a purpose-designed survey as the primary data collection instrument, developed to examine the experiences of lecturers and facilitators delivering laboratory-based teaching in electronic and computer engineering disciplines during the COVID-19 pandemic. The aim was to explore how laboratory instruction was adapted in higher education institutions (HEIs) across Ireland during the shift to remote and hybrid teaching environments.

Survey Design and Validation

The survey was developed through a multistage design process informed by both literature on online STEM education during crises and preliminary interviews with faculty members to identify relevant domains/areas for investigation. Key themes included traditional lab delivery practices, adaptations during the pandemic, technology use, perceived effectiveness, and pedagogical challenges.

To ensure content validity, the draft survey instrument underwent a review by a panel of two subject matter experts in engineering education and online pedagogy. Their feedback was used to refine question wording, sequencing, and alignment with the study's research objectives. A pilot test was then conducted with fellow lecturers from the University of Limerick's Electronics & Computer Engineering (ECE) Department. Responses from the pilot were analyzed to assess clarity, internal consistency, and timing. As a result, minor revisions were made to reduce ambiguity and improve usability.

The final version of the survey consisted of 26 questions, using a mix of open-ended, Likert-scale, multiple-choice, and ranking-type formats. Open-ended questions allowed for detailed qualitative input, while the closed-ended formats provided structured data for quantitative analysis.

Sampling and Data Collection

The survey targeted academic staff involved in laboratory instruction in electronic, electrical, and computer engineering programs at 18 Irish HEIs offering relevant undergraduate degrees. A purposive sampling strategy was used to identify institutions and individuals with direct experience in lab teaching. Contacts were identified via institutional websites, departmental directories, and professional networks, and survey invitations were emailed directly to faculty members.

To maximize reach and response rate, two reminder emails were sent over a four-week collection period. The survey was administered online via Qualtrics, ensuring a user-friendly and secure response environment. Participation was entirely voluntary, with informed consent obtained at the outset. Responses were anonymized, and no identifying information was collected. The study was reviewed and approved by the host institution's Research Ethics Committee, and all procedures conformed to standard ethical guidelines for research involving human subjects.

Data Analysis

The analysis followed a mixed-methods approach, incorporating both qualitative and quantitative elements. Responses to closed-ended questions were analyzed using descriptive statistics (means, frequencies, and standard deviations) to summarize trends across institutions. Statistical analysis was conducted using IBM SPSS Statistics, and results were cross-tabulated by institution type and lab delivery format to identify emerging patterns.

Responses to open-ended questions were analyzed using an inductive thematic analysis approach, based on the six-phase method outlined by Braun and Clarke (2006). This involved familiarization with the data, initial code generation, theme development, and iterative refinement. Coding was conducted manually and peer-reviewed by a second researcher to enhance reliability. Emergent themes included adaptability of lab content, access to remote tools, and changes in assessment practices, among others.

By combining rigorous survey validation, targeted sampling, and a structured approach to qualitative and quantitative analysis, this methodology offers a robust foundation for understanding how Irish engineering educators navigated the challenges of remote lab instruction during the pandemic.

IV. FINDINGS & DISCUSSION

Prior to the COVID-19 pandemic four distinct approaches to laboratory delivery were identified: traditional, project-based, mixed, and online. Traditional labs were defined as those conducted face-to-face in a physical laboratory setting, utilizing hardware and/or software specific to that environment. These sessions typically lasted two hours and were evaluated through written reports or other assessment methods. Project-based labs, on the other hand, involved students working in groups over the course of several weeks on a specific project. In this model, instructors or tutors served as facilitators during scheduled lab hours, and assessment was based on written reports or other forms of evidence documenting the completion of the project. Mixed labs incorporated elements of both traditional and project-based lab delivery within the same module. Finally, online labs were delivered remotely, with all activities conducted through virtual platforms.

Survey responses revealed that the predominant method of laboratory delivery prior to the pandemic was the traditional model. Specifically, 75% of respondents indicated that traditional laboratory sessions were used in their module delivery. Project-based labs were employed by 13% of respondents, while 9% of respondents reported using a mixed approach that combined both traditional and project-based methods. Notably, 3% of respondents had already incorporated some form of remote or online delivery for laboratory sessions prior to the onset of the pandemic, suggesting a degree of preparedness for the transition to online learning that occurred when remote delivery became necessary.

The pandemic/remote learning laboratory sessions considered or implemented by respondents were diverse. In many instances, respondents reported trialling two or three different methods during the pandemic, or even incorporating multiple approaches within the same module. For example, some utilized a combination of "take-home" labs alongside simulations, or simulations followed by a Project-Based Learning (PBL) assignment. A total of 81 distinct pandemic/alternative delivery methods were identified across all respondents, which were subsequently grouped into five broad categories, as outlined in Table I. As anticipated from the existing literature, the most commonly adopted methods were Learning Simulations and Remote/Virtual Lab Implementations, which were the preferred choices across the various courses and approaches. It is important to note that "take-home" lab kits, physical hardware mailed to students, and similar resources were all classified as “Remote/Virtual Lab Implementations” in this study.

TABLE I
PANDEMIC LAB DELIVERY METHODS CONSIDERED

Pandemic Delivery Method(s)	# Respondents
Learning Simulations	21
Remote/Virtual Lab Implementations	31
Use of Electronic Lab Notebooks/E-Books	3
Using Portfolios/Formative Assessments	8
Project-Based Learning	17
Other	1

Respondents were asked to assess the perceived effectiveness of their chosen delivery methods on a 5-point Likert scale, ranging from “Extremely Effective” to “Not Effective at All.” Figure 1 illustrates the participants' responses regarding the effectiveness of these alternative delivery methods.

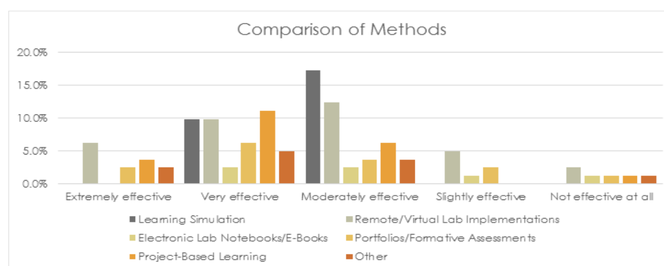

Fig. 1 Perceived Effectiveness of the different Lab Delivery Methods.

Overall, Remote/Virtual Lab Implementations were viewed as the most effective and popular option among the survey participants, followed by Learning Simulations and Project-Based Learning. Portfolios/Formative Assessments, Other methods, and E-Lab Notebooks ranked lower in perceived effectiveness, with respondents indicating varying levels of success with these approaches.

Of these considered methods, Table II shows which alternative methods were actually chosen for implementation. The use of simulations and simulation tools was the most popular choice implemented by the survey participants. Simulation software packages considered in this option included Proteus, ViciLogic, LTSpice, OrCAD Lite and TinkerCAD. Based on the survey responses, free or readily available versions of the software simulator(s) were preferred, as “free was a major motivator to equalise access”. By replacing the physical building of circuits with circuit simulations, participants felt that “[it] retained much of the fundamental purpose of the labs”.

TABLE II
PANDEMIC LAB DELIVERY METHODS ACTUALLY IMPLEMENTED

Alternative Delivery Method Chosen	Count
Learning Simulations	14
Remote/Virtual Lab Implementations	12
Use of Electronic Lab Notebooks/E-Books	0
Using Portfolios/Formative Assessments	0
Problem-Based Learning	2
Other	5

The second most commonly adopted approach for remote laboratory delivery was the use of remote/virtual labs, which frequently involved the distribution of home or "take-away" lab kits to students. These kits typically contained a microcontroller or evaluation board, breadboard, and various components, enabling students to construct circuits independently at home. Respondents expressed that these kits helped maintain the "practical/physical approach to engineering" that many departments had integrated into their curricula. Despite acknowledging the additional overhead and workload involved—both for instructors and technical/support staff—in preparing and distributing the lab kits, respondents reported that the inclusion of a physical component in remote labs proved motivating for students. Although not always financially viable or logistically feasible, respondents noted that providing home lab kits created a solid foundation for students to gain hands-on experience and foster independent learning.

The third most popular delivery method (categorized as "Other" by most respondents) involved a combination of simulation-based labs followed by practical sessions conducted using home lab kits. This mixed approach allowed students to first engage with virtual simulations before applying their knowledge in hands-on experiments, enhancing their understanding through a blend of theoretical and practical components.

The fourth method selected by respondents was Problem-Based Learning (PBL), which was considered an effective remote lab delivery strategy. Respondents highlighted that PBL "facilitates learning in context" and supports students in achieving key engineering program outcomes. Additionally, they noted that PBL could lead to "deeper and more meaningful learning" by encouraging students to tackle complex, real-world problems.

Interestingly, none of the respondents selected E-Notebooks or Portfolio/Formative Assessment-based methods for remote lab delivery, suggesting a preference for more interactive or hands-on approaches to virtual learning.

Finally, in terms of potential changes or improvements to their laboratory delivery methods for future iterations, respondents were asked to identify strategies for overcoming limitations in their current methods and ways to enhance the overall student laboratory experience. The responses were analysed through iterative thematic analysis, as outlined in [27], and categorized into recurring themes.

The most prominent theme identified was the integration or expansion of "take-home" lab kits. Many respondents expressed interest in combining these kits with simulations or transitioning to fully kit-based labs for future remote implementations. A key benefit highlighted was the potential for these kits to boost student engagement, with several respondents noting that incorporating physical components would “encourage student interaction with the online labs.”

In relation to this, respondents who had already implemented "take-home" kits foresaw changes to the kit contents in subsequent offerings. While the overall concept of the kits was deemed successful, several respondents mentioned that the equipment and components would need updating based on lessons learned from previous implementations. One respondent commented “First time around, we were a bunch of enthusiasts, putting in the work and enthusiasm, but not very efficient.” Another noted that they were “constrained by the components available in the kit, requiring me to develop a new suite of labs.” Some also suggested modifications to the software tools used in conjunction with the kits and simulations to improve the experience.

A second area identified for improvement was the facilities and infrastructure required for online lab sessions. Respondents emphasized the need for better computing, audio, and video equipment, as well as higher-speed internet connections, to facilitate smoother and more efficient lab experiences. Interestingly, this concern extended beyond students, with respondents highlighting the importance of properly equipping teaching assistants (TAs). As one lecturer explained, “We need to be able to involve Teaching Assistants better,” which necessitated “ensuring TAs have the proper setup, including purchasing additional kit if necessary.”

The next major improvement noted by respondents was related to course material and assessment strategies. Many felt that the creation of preparatory or introductory materials for students would help them "get up to speed" more quickly, as developing these materials for remote delivery had been time-consuming. Resources such as installation guides, video support materials, and FAQs were suggested as tools that could enhance the lab experience. Additionally, respondents reflected on their experiences with online assessment, emphasizing the value of continuous assessment. One respondent noted, "Continuous assessment is a key element in this approach, as it allows problems to be identified early on, which is crucial in an online environment where it can be difficult to gauge student progress."

Some respondents indicated that no major changes were necessary for future iterations of their online labs. Of the 33 responses, six participants felt that their current approach was optimal under the given circumstances and would be maintained. They stated that they were already "delivering the best possible solution" and would "continue as is." Another four respondents noted limitations in improving the online lab experience due to factors such as cost and the lack of viable alternatives. For example, one respondent remarked "It would be nice to enable students to do hardware-based work at home, but the cost may not allow it." Others expressed concerns about the inefficiency of collaboration in online project-based learning. However, a few respondents felt that the shift to virtual delivery might have benefitted certain modules. As one lecturer observed "The module may be more suited to online delivery," suggesting that some remote adaptations were well-suited to specific course formats.

V. Conclusion & Further Work

This study has examined how electronic and computer engineering lecturers in Irish Higher Education Institutions (HEIs) responded to the challenges of delivering laboratory-based education during the COVID-19 pandemic. By analyzing survey data from 33 respondents across 12 institutions, the research offers a valuable snapshot of pedagogical adaptation under crisis conditions. More importantly the findings point toward sustainable innovations in practical STEM education that can inform global practices in both emergency and standard instructional contexts.

Five key strategies emerged from the data — learning simulations, remote lab kits, electronic lab notebooks/e-books, formative assessment tools such as portfolios, and Problem-Based Learning (PBL) — each with distinct pedagogical affordances. While these methods were adopted in response to the disruption of face-to-face instruction, many exhibit clear potential for integration into long-term, blended, or fully online education models across diverse international settings.

Flexibility, student autonomy, and enhanced engagement were among the most widely cited benefits of remote lab methods, particularly in asynchronous environments that allow learners to work at their own pace and from any location. These advantages are especially relevant for situations where student populations may be geographically dispersed, or where institutions seek to expand access to hands-on learning without the constraints of physical lab infrastructure. Likewise, the modular and scalable nature of remote lab kits and virtual simulations presents opportunities for deployment in developing education systems, remote regions, or resource-constrained institutions.

However, the study also highlights limitations that transcend national boundaries. Technical issues, reduced tactile interaction with equipment, and diminished peer-to-peer collaboration are challenges that educators worldwide must address. These findings reinforce the need for thoughtful curriculum design that balances remote tools with authentic, hands-on experiences, potentially through hybrid delivery models or mobile lab solutions.

While rooted in the Irish context, the lessons learned from this survey are highly transferable. As institutions globally continue to reimagine engineering education in a digitally enhanced era, the strategic use of low-cost technologies, flexible learning pathways, and experience-based assessment models can guide curriculum reform. Moreover, international educators can draw on this research to benchmark their own approaches to virtual lab delivery, especially in disciplines where practical application is integral to learning outcomes.

Looking ahead, further research should explore how the most effective remote lab strategies evolve in post-pandemic education. Longitudinal studies across different countries and institutional types could help identify which innovations persist and which revert to traditional formats. Additionally, deeper qualitative exploration through case studies or interviews would provide richer insight into the lived experiences of educators and students navigating this evolving pedagogical landscape.

In sum, the pandemic accelerated the adoption of digital tools in engineering education—but it also catalyzed a broader pedagogical shift. By capturing how Irish lecturers adapted under pressure, this study contributes to a growing global conversation on how best to deliver meaningful, equitable, and future-proof STEM education in a rapidly changing world.

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