HELP – Home Electronics Laboratory Platform –Development And Evaluation

Martin HILL
Dept. Of Electrical and Electronic Engineering, Munster Technological University, Ireland, martin.hill@mtu.ie

Michael MURRAY
Dept. Of Electrical and Electronic Engineering, Munster Technological University, Ireland, michael.murray@mtu.ie

Tom O MAHONY
Dept. Of Electrical and Electronic Engineering, Munster Technological University, Ireland, tom.omahony@mtu.ie

See next page for additional authors

Authors
Martin HILL, Michael MURRAY, Tom O MAHONY, Raul ONET, and Marius NEAG

HELP – Home Electronics Laboratory Platform –Development and evaluation

Martin Hill
Dept. Of Electrical and Electronic Engineering, Munster Technological University
Cork, Ireland
ORCID: 0000-0002-5018-1992

Michael Murray
Dept. Of Electrical and Electronic Engineering, Munster Technological University
Cork, Ireland

Tom O'Mahony
Dept. Of Electrical and Electronic Engineering, Munster Technological University
Cork, Ireland
ORCID: 0000-0002-0658-5797

Raul Onet
Dept. of Bases of Electronics, Technical University of Cluj-Napoca
Cluj-Napoca, Romania
ORCID: 0000-0003-0891-2015

Marius Neag
Dept. of Bases of Electronics, Technical University of Cluj-Napoca
Cluj-Napoca, Romania
ORCID: 0000-0003-2761-6318

***Conference Key Areas**: Engineering Skills and Competences, Lifelong Learning for a more sustainable world, Innovative Teaching and Learning Methods*
***Keywords**: Engineering laboratories, take-home laboratories, independent learning, troubleshooting*

ABSTRACT

In response to the COVID pandemic, many of our undergraduate students were supplied with custom development kits to undertake their electronic laboratory activities at home. Following our return to on-campus teaching, we plan to combine on-campus laboratory sessions with at-home experiments taking advantage of both on-campus and at-home experimental work while avoiding some of the limitations experienced during remote teaching. The goal is to embed active learning as a key part of a long-term strategy to enable students to better manage their learning and to maximise the analytical engagement with lecturers in a hybrid blend of on-campus and remote activities.

In this paper, we report on three generations of the at-home laboratory kit developed by the author's institute and partners in the Erasmus+ project "Home Electronics

Laboratory Platform (HELP)”. The HELP kit comprises a portable signal generator and measurement instrument and a custom electronic board, which includes several functional blocks alongside the usual breadboard for assembling circuits with discrete components. The motivation for the design of each generation is introduced and the desired functionality and its implementation are described.

The impact and user experience with the kits have been assessed through student surveys and staff focus groups in the HELP consortium partners. The main themes associated with take-home electronics laboratories have also been explored in a workshop with HELP partners and contributors from other universities across Europe and the USA. This work is summarised and future potential technical and pedagogical developments are outlined.

1 INTRODUCTION

Fundamental undergraduate courses in electronics require practical experiments building and characterising circuits using laboratory equipment. This experience is crucial because it allows students to acquire essential skills such as setting up and conducting an experiment, using specialised equipment, testing, debugging, data interpretation and documentation. In our curriculum and teaching practice we seek to design our laboratory practice to achieve the 13 ABET objectives for students completing a laboratory series in an engineering undergraduate programme (Feisel and Peterson 2002) as listed in Table 1.

ABET Objectives	
Instrumentation	Creativity
Models	Psychomotor
Experiment	Safety
Data Analysis	Communication
Design	Teamwork
Learn from Failure	Ethics
Sensory Awareness	

Table 1 ABET Undergraduate Engineering Laboratories Objectives

After reviewing our traditional pre-COVID practice we determined that to achieve these objectives more laboratories should focus on providing opportunities for students to develop their own solutions, providing more design opportunities, involving formal collaborative learning and including a more explicit focus on health, safety and the environment. Laboratories that adopt enquiry, problem or project-based approaches are good candidates to improve alignment with desired outcomes such as the ABET objectives (Vesikivi et al. 2020).

The dominant approaches to laboratory practice have been in-person, simulation-based or remote laboratories. Existing research has explored ways of doing each along with their relative advantages and limitations, (Corter et al. 2011; Brinson 2015)An alternative to these three modes of delivery is the take-home laboratory which has received little attention within the engineering education research literature. A take-home laboratory (also called a distance laboratory) can be defined as an educational laboratory where students perform hands-on experiments with physical devices in their own homes.

In this article, we describe the development of take-home laboratory equipment for electronic engineering students in response to the COVID-19 pandemic. The kit has subsequently been developed to explore enhanced delivery using a blended laboratory teaching approach. Students are sent a bespoke low-cost Home Electronics Laboratory Platform (HELP) platform consisting of a combination of offthe-shelf portable test tools and a custom circuit board where students could perform typical laboratory activities. Following the success of the take-home system during COVID-19 teaching an ERASMUS+ EU project (HELP) was funded to further develop new application-driven versions of the platform. The HELP platform is open-source and so can be easily replicated within other institutions or purchased for a low cost. It can be used to enable learners to develop a rich understanding of core concepts associated with Electronic and Embedded Systems Engineering.

It can also expand access to engineering education for disadvantaged learners due to its low cost and flexible learning approach. For online and distance learning environments, low-cost take-home laboratories can increase student enrolment, help motivate learners and develop practical skills (Kennepohl 2017). This richer understanding also impacts more traditional in-person environments as take-home laboratories can be used to realise project-based experiences which have been shown to positively impact learning and enhance student retention (Vesikivi et al. 2020).

In this paper, we report on three generations of the at-home laboratory HELP kit developed by the author's institute and partners We draw on our experiences to discuss some potential applications of the current system and explore the potential for further development.

2 TAKE-HOME LABORATORY DEVELOPMENT

The traditional, on-campus, laboratory is a key element of conventional teaching and learning engineering subjects. In our programmes, 40-60% of student contact hours are allocated to application classes (lab/project). For electronics, this typically involves weekly application classes with activities focused on circuit analysis and characterisation through simulation using SPICE-based programs and by performing experiments on well-defined test setups assembled by students during the lab class. Typically, these activities require a set of standard laboratory equipment (power source, signal generator, oscilloscope, multimeter and breadboard as shown in Figure 1), and a set of electronic components, wires and connectors. This equipment is most often set up in a laboratory class with students timetabled to have 2 hours of practice time per module in the laboratory each week to carry out the required circuit experiments.

There is limited published literature on take-home laboratories with reported developments to support a variety of subject areas including mechatronics (Stark et al. 2013), fluid mechanics (Meng et al. 2018), mechanical engineering (Schajer 2021), control systems (Jouaneh, Boulmetis, and Palm 2013), embedded systems (Kommu, Uttarkar, and Kanchi 2014), digital electronics (McCarthy, Murphy, and Popovici 2022; Oliver and Haim 2009; Ruo Roch and Martina 2022) and communications (Popović et al. 2020). In the majority of these papers, the focus is on describing the kit and then describing some typical experiments to outline its use and there is little reporting of data-driven development of the kits after initial deployment.

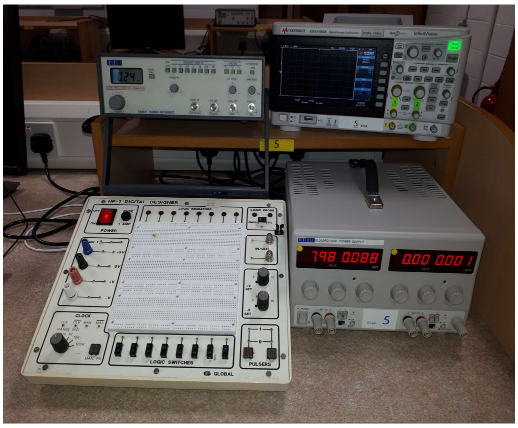

Fig. 1. Typical laboratory setup for an undergraduate electronics laboratory

Topic	**Required features**	**Measurements**	**HELP**
Embedded Systems development VHDL	Advanced microcontroller FPGA		
Embedded Systems Basics	Basic Microcontroller	AC Values Timing signals	V2.0
Analog integrated amplifiers Sensor interfacing Transistors Amplifiers ADC/DAC converters	Bipolar power	AC Values Timing signals	V1.1
Sequential Digital circuits Passive AC circuits Active AC circuits	Clock signals AC signal source	AC Values Timing signals	V1.0
Combinational Digital circuits Passive DC circuits Active DC circuits	Digital I/O DC Supply Variable voltages	DC values	V1.0

Table 2 Progression of required circuit experiments in undergraduate electronic engineering

2.1 HELP V1.0

The HELP V1.0 kit presented in Figure 2 was developed in response to the Covid19 pandemic. It consists of a compact, standalone 3-in-1 handheld instrument - the Hantek 2D42 portable scope (“Hantek 2000 Series Product Description” 2023) - and a USB-powered electronic board, designed specifically for this purpose. The Hantek 2D42 instrument provides an Oscilloscope able to monitor two channels for frequencies up to 40MHz, an Arbitrary Waveform Generator (AWG) able to provide sine- and square-waves with programmable frequency (up to 1MHz) and amplitude (up to 2.5Vpk), as well as a Digital Multimeter.

Fig. 2. HELP kit V1.0 laboratory board and board in carry case with Hantek 2D42

2.2 HELP V1.1

The HELP V1.1 kit presented in Figure 3 was developed to address usability issues encountered with HELP V1.0 and to also add additional functionality to expand the range of experiments that students could carry out as shown in Table 2. The Hantek 2D42 was upgraded to the Hantek 2D72 as this part had more parts in stock and this provides an Oscilloscope able to monitor two channels for frequencies up to 70MHz.

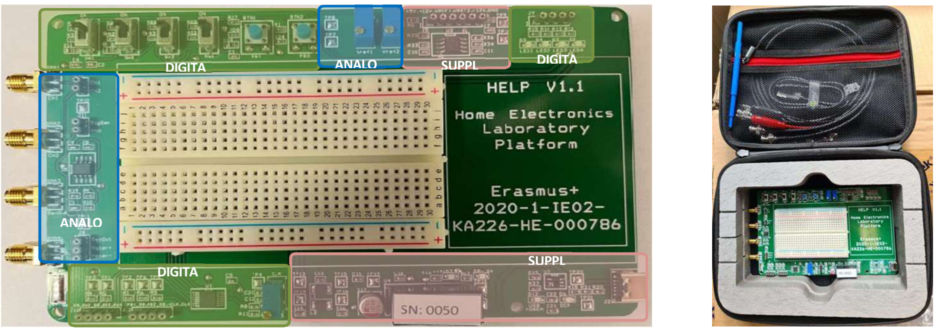

Fig. 3. HELP kit V1.1 laboratory board and board in carry case with protective foam

As with HELP V1.0, the V1.1 kit includes the breadboard, required wires and cables for all experiments, and the HELP PCB which also includes several functional blocks implemented on-board that expand the range of experiments students can perform. The main additional features are:

- symmetrical supply lines, ±12V
- power amplifier able to scale up the signal provided by the Hantek instrument, to an amplitude of maximum 10Vpk for the sinewave.
- DC voltage sources with values adjustable manually between ±10V
- digital clock generator, with frequency adjustable from 0.3Hz to 210Hz
- several switches and push buttons (both straight and debounced) to generate logic inputs and LEDs to monitor logic states.

Figure 4 presents the block diagram of the HELP V1.1 board. The functional blocks are grouped in three sections: the power supply section, the analog section and the digital section.

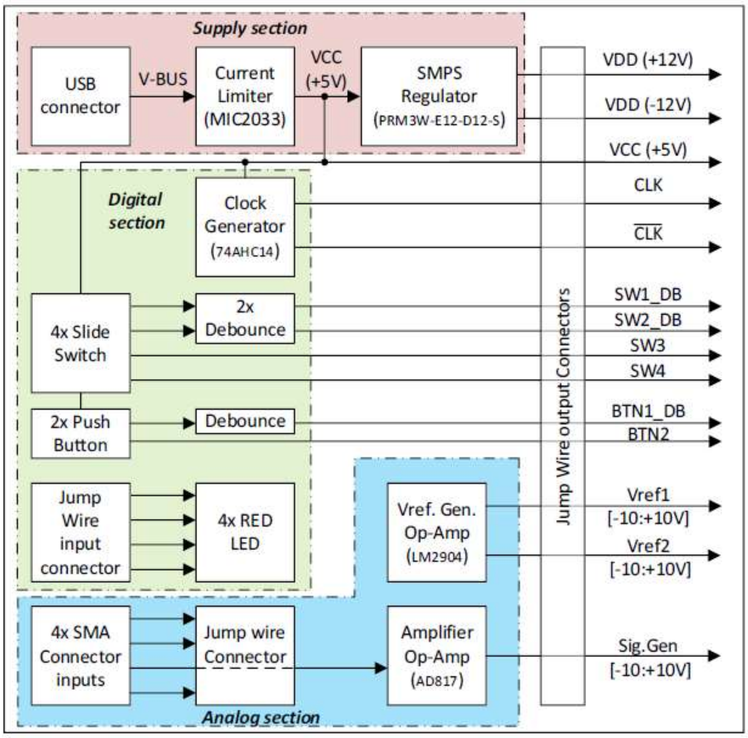

Fig. 4. Schematic of the Helpkit V1.1 electronic Board

2.3 HELP V2.0

The HELP V2.0 kit, presented in Figure 5, was primarily developed to reduce dependence on the Hantek 3-in1 instrument which was increasing in cost and restricted options for potential users. HELP V2.0 was developed to have an integrated Arbitrary Waveform Generator (AWG) able to provide sine- and square waves. The inclusion of this feature was accomplished using an Arduino Nano controlling an AD9833 Programmable Waveform Generator. The Nano board provides additional functionality expanding the range of experiments that students could carry out to include basic microcontroller programming as shown in Table 2. The kit now requires an external oscilloscope and multimeter but many institutes will have invested in such portable measuring equipment and can use the HELP kits without incurring any further cost. HELP V2.0 includes the Help Kit V1.1 electronic board functions and in addition, includes:

- Onboard Signal generator: Arduino Nano, Display, Rotary encoder
- Arduino Nano pins available for coding

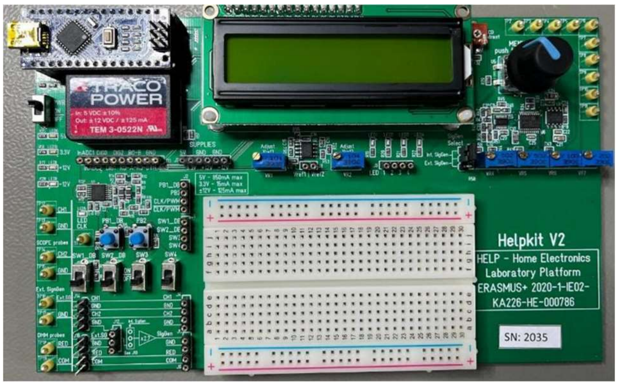

Fig. 5. HELP kit V2.0 laboratory board with the same dimensions as V1.1

The system schematic for V2.0 is shown in Fig 6. The supply section uses a different chipset with increased performance and power consumption limited to 2.5W from the 5V USB supply. The digital section has the same switch inputs and LED outputs as V1.1 but has additional ADC and PWM lines available from the Arduino Nano. The system clocks are also generated from the Arduino Nano which configures the output from the AD9833 Programmable Waveform Generator in the Analog section and amplifier gains from the generated AC signals.

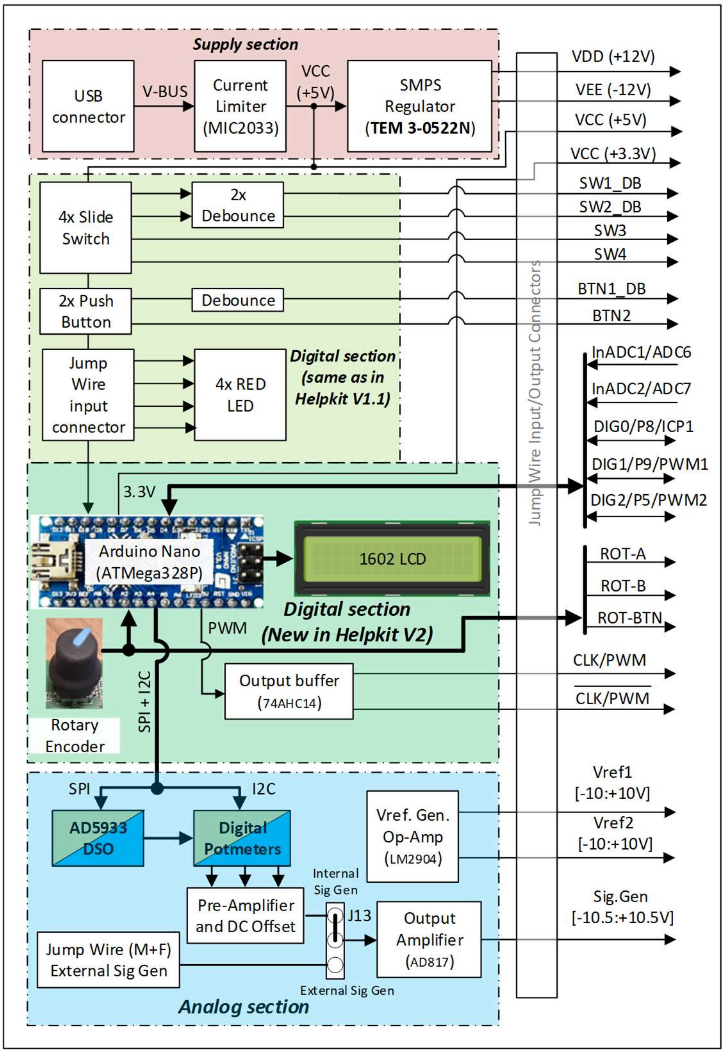

Fig. 6. Schematic of the Helpkit V2.0 electronic Board

3 RESULTS

The HELP kits have been developed and deployed over the past 6 semesters and we have tried to evaluate their impact and based on that data evolve the kit and our teaching practice to better meet the desired learning objectives for our students in laboratory sessions. In this section, we report on some of the feedback from HELP kit users and explore some possibilities for future development of the HELP kit.

3.1 Evaluation of HELP kit

The HELP kit has been used by students in several university programs at different stages of undergraduate development. Feedback on the experience of students and lecturing staff (O Mahony et al. 2022) has been gathered via surveys and focus groups. Initial feedback from learners gathered via surveys has been positive. As shown in the results of one survey presented in Fig 8, students were very positive about the lack of time constraints in completing tasks and also reported a high level of peer support in completing the experimental tasks. Relative to the on-site laboratories, the students found the more independent nature of the learning challenging and many experienced a lack of focus.

In a blended laboratory approach, the laboratory practice in pilot modules has been modified to include an increased portion of project-based activities. This involved restructuring the module activities from 100% directed exercises to a hybrid approach with 40-100% project-based activities. Modules, where students are introduced to new concepts, experimental setups, and measurements, include a higher proportion of directed learning in the early stages of the module. Student feedback has also been positive in this development.

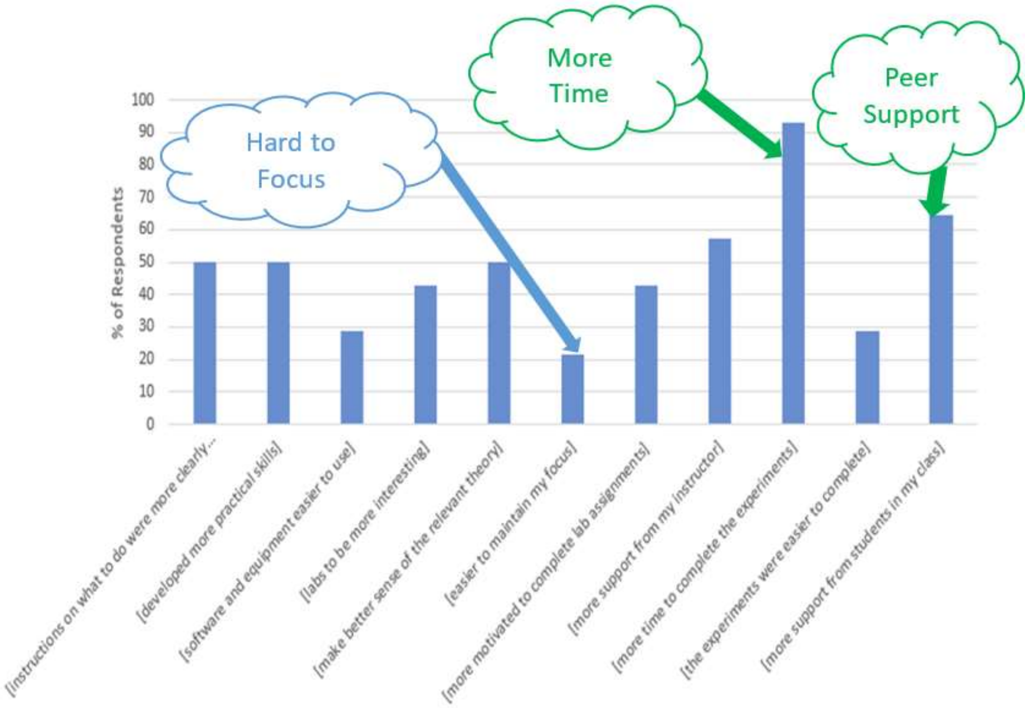

Fig. 8. Initial student feedback on HELP Take-home Laboratories

3.2 Future Development

HELP V2.0 has expanded the range of laboratory activities that can be supported with at-home delivery from our initial development as shown in Table 2. The Table also highlights those areas where undergraduate students will require additional equipment to meet their circuit design and embedded systems development laboratory needs. Future HELP developments could address the following topics:

- Cost reduction – the requirement for a two-channel oscilloscope with HELP V2.0 adds significantly to overall system cost and size for portability. The current cost for a full HELP kit is approximately €250 and this may be too costly for large scale deployment. A target cost would be to reduce this price by 50%. This could be addressed by adding a built-in oscilloscope on the HELP board with a software interface via the USB port.
- Added functionality – The kit could add FPGA and higher-power microcontrollers to the design to allow for laboratory exercises using these systems to be completed. These components could be used to develop the in-built scope function. This would make the system more complex and could reduce the simplicity of use that is attractive to students in their early years.
- Modify laboratory practice and assessment to encourage independent and collaborative activity enabled by take-home kits.
- Expand the online peer and tutor supports available to assist students and avoid excess time in troubleshooting or the associated lack of focus.

4 SUMMARY AND ACKNOWLEDGMENTS

Three generations of the at-home HELP laboratory kit which comprises a portable signal generator and measurement instrument and a custom electronic board for circuit and embedded system experimentation have been presented. The learning objectives of electronic laboratory practice have been outlined and the motivation, functionality and application level of each generation is described.

The impact and user experience with the kits has been assessed through student surveys and staff focus groups. The main benefit reported by students was increased experimentation time while the main problem encountered was in troubleshooting in the absence of tutor support. The take-home experience has been positively received by staff and students and future potential technical and pedagogical developments were outlined.

Acknowledgement. This research was funded by the ERASMUS+ Programme 2020 KA2 High Education Project nº: 2020-1-IE02-KA226-HE-000786

REFERENCES

Brinson, James R. 2015. “Learning Outcome Achievement in Non-Traditional (Virtual and Remote) versus Traditional (Hands-on) Laboratories: A Review of the Empirical Research.” *Computers & Education* 87 (September): 218–37. https://doi.org/10.1016/J.COMPEDU.2015.07.003.

Corter, James E., Sven K. Esche, Constantin Chassapis, Jing Ma, and Jeffrey V. Nickerson. 2011. “Process and Learning Outcomes from Remotely-Operated, Simulated, and Hands-on Student Laboratories.” *Computers and Education* 57 (3): 2054–67. https://doi.org/10.1016/j.compedu.2011.04.009.

Feisel, Lyle D., and George D. Peterson. 2002. “A Colloquy on Learning Objectives for Engineering Education Laboratories.” *ASEE Annual Conference Proceedings*, no. January 2002: 4531–42. https://doi.org/10.18260/1-2--11246.

“Hantek 2000 Series Product Description.” 2023. 2023. http://hantek.com/products/detail/13174.

Jouaneh, Musa, J. Boulmetis, and W. Palm. 2013. “Take-Home Experiments in Engineering Courses: Evaluation Methods and Lessons Learned.” *International Journal of Engineering Education* 29 (1): 139–53.

Kommu, Aruna, Naveen Kumar Uttarkar, and Raghavendra Rao Kanchi. 2014. “Projects for Embedded System Laboratory Using” 3 (978).

McCarthy, Kevin G, Colin C Murphy, and Emanuel M Popovici. 2022. “Re-Engineering of Undergraduate Analogue Electronics Laboratories during Covid-19.”

Meng, Fanhe, Bernard J Van Wie, David B Thiessen, and Robert F Richards. 2018. “Design and Fabrication of Very-Low-Cost Engineering Experiments via 3-D Printing and Vacuum Forming.” *International Journal of Mechanical Engineering Education* 47 (3): 246–74. https://doi.org/10.1177/0306419018768091.

O Mahony, Tom, Martin Hill, Annie Duffy, Michael Murray, Raul Onet, Marius Neag, and Luis De La Torre Cubillo,. 2022. “A Take Home Laboratory to Support Teaching Electronics : Instructors Perspectives and Technical Revisions A Take Home Laboratory to Support Teaching Electronics : Instructors Perspectives and Technical Revisions,” no. December: 0–16. https://doi.org/10.24840/XXXX-XXXX.

Oliver, Juan P, and Fiorella Haim. 2009. “Lab at Home : Hardware Kits for a Digital Design Lab” 52 (1): 46–51.

Popović, Zoya, Gerald Artner, Gregor Lasser, Christoph F Mecklenbräuker, and Brewster S Angle. 2020. “Electromagnetic-Wave Fun Using Simple Take-Home Experiments,” 100–106.

Ruo Roch, Massimo, and Maurizio Martina. 2022. “VirtLAB: A Low-Cost Platform for Electronics Lab Experiments.” *Sensors (Basel, Switzerland)* 22 (13): 4840. https://doi.org/10.3390/s22134840.

Schajer, G S. 2021. “A Build-at-Home Student Laboratory Experiment in Mechanical Vibrations.” *International Journal of Mechanical Engineering Education* 50 (2): 240–52. https://doi.org/10.1177/03064190211025954.

Stark, Brandon, Zhuo Li, Brendan Smith, and YangQuan Chen. 2013. “Take-Home Mechatronics Control Labs: A Low-Cost Personal Solution and Educational

Assessment.” https://doi.org/10.1115/DETC2013-12735.

Vesikivi, Petri, Minna Lakkala, Jaana Holvikivi, and Hanni Muukkonen. 2020. “The Impact of Project-Based Learning Curriculum on First-Year Retention, Study Experiences, and Knowledge Work Competence.” *Research Papers in Education* 35 (1): 64–81. https://doi.org/10.1080/02671522.2019.1677755.