Leveraging commercial technologies to implement hands-on project-based learning of engineering principles

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Abstract: Hands-on project-based learning has been shown to increase students’ attention and understanding of engineering concepts. However, for experimentation to play an equal role in engineering education alongside theory and simulation, presents significant challenges to educators in terms of cost, accessibility and ratio.

These challenges can be overcome by collaborations between educators and industry to leverage commercial investment into hardware and software tools that can be purposed specifically towards engineering education. For example, as industry drives advances in analogue-to-digital chips, instrumentation companies are able to provide oscilloscopes at a cost and size such that each EEE student at The University of Manchester can now receive their own. Using “a lab in your bag”, practical assignments and students’ own experiments can be completed at home. This is also made possible through high level programming environments that abstract programming syntax, without detracting from the fundamentals concepts that must be taught.

As educational products are developed based upon industry technology, experimentation is becoming relevant and accessible to every student, even in traditionally theory-based courses such as RF and Communications. By enabling students to do real engineering, they graduate as inspired, employable innovators, equipped to tackle the grand challenges we face.

Keywords: hands-on, project-based, experimental, engineering, student instrumentation, self-study

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1. INTRODUCTION

A central focus of engineering education is to ensure graduating engineers have the ability to “design effective solutions that meet societal needs” (Sheppard, 2003). Traditionally, engineering education has built on a foundation of sciences and mathematics learning. Over the last 10 years, increased emphasis has been placed on providing hands-on, project-based learning in engineering education. The value of hands-on learning experiences in engineering education has been well-documented (Lamb et.al, 2010), and is driven by both a need to
improve student engagement and retention, as well as the need to supply engineering graduates with the right skills for industry.

There have been significant advancements in recent years on incorporating hands-on project based learning into engineering education, a view supported by Thomas (2000). However, there are still many challenges and gaps in delivering a fully immersive hands-on learning experience throughout the tenure of a student’s time in engineering.

Currently, delivering hands-on experiences to students typically focuses on improving lab or project-based work to provide more real-world engineering examples. For example, many Electronic Engineering departments have labs already dedicated to providing hands-on learning for circuit design and implementation, but introducing hands-on learning experiences for subjects such as power electronics or communications can be more challenging due to the practicality and cost of setting up hardware-based labs. According to Feisel and Rosa (2005) in ‘The Role of the Laboratory in Undergraduate Engineering Education’, “...engineering department budgets are not always adequate to meet the needs of a modern instructional laboratory, especially those requiring significant amounts of hands-on involvement.” In these subject areas, it is less feasible to provide each student with access to emerging technologies like smart grid, or communications system design tools.

Another barrier to delivering hands-on experiences is the distribution of an undergraduate student’s time spent in lectures, labs and self study. Traditionally, the majority, if not all, of student hands on experiences occur in the laboratory. To increase time spent by students on experimentation, students need access to hands-on learning outside of the laboratory.

In this paper, we will examine the area of self study and improving hands-on experiences by leveraging low cost technologies to enhance individual learning of engineering concepts.

### 2. SELF STUDY APPROACHES

A typical 10 credit engineering module (100 hours of study) consists of up to 50-70 hours of self study. Often this self study time is directed towards completion of lab reports, preparation and completion of coursework or tutorial materials, and further reading to enhance understanding of the principles covered in lectures and labs.

A variety of approaches are used by academics to provide students with a spectrum of tasks to approach outside of the lecture and lab: these include tutorial style questions; writing up of in-lab or in-lecture experiences; simulation tasks to explore engineering principles; or remote web-based experiments to enable them to access different experiments than those presented in the lab.

Through tutorial questions and report writing, students are asked to reflect on concepts learned in the lecture or lab, which can provide educators with a method of assessing understanding of the engineering concepts. Students can review lecture notes and logbooks, as well as textbooks and other online resources, but students lack access to tools outside of a
university campus to further explore and experiment with concepts using a practical approach. The limitation prevents a student from re-enforcing the link between theory and the physical world.

With the increasing use of internet technologies in undergraduate education, educators are turning to simulation tasks or remote web experiments (Bourne et. al., 2005) to try and increase the amount of time a student can explore an engineering concept learnt in the classroom.

Computer simulations are commonly used in courses which are traditionally more mathematically intensive, such as signals and systems, or communications. The purpose is to allow the student to experiment with the effects of equations on known signals. The simulations provide simplistic views of data shown on graphs and tables, which whilst factual, do not necessarily give the student a full appreciation of what happens in the real physical system. For example, if we consider a mass on a spring, it can have its displacement from rest shown on a graph, but this does not capture the imagination with the same vigour as seeing the mass move or giving the student any appreciation of how to implement the measurement to provide the data shown on the graph.

In addition, there have been a number of universities adopting web-based experiments to allow a student to connect to a real experiment through the internet. These sessions present the student with an experience similar to an in-lab experiment, and ask them to perform a series of actions to collect and analyse data (Hanson et al., 2008). Remote labs provide an appealing mechanism to give a large number of students access to a single experimental setup, reducing the cost of replicating equipment. There can be a high setup and maintenance cost associated with remote labs, due to the nature of the IT infrastructure that is required to enable students to individually access the experiment with no conflicts. There can also be perceived challenges with the number of potential breaking points within the system; and student experience can be affected by poor internet connection or problematic connection with equipment at the remote site which the student has no control over.

Providing specific assignment work goes some way to encourage the student to continue to engage with the subject outside of the lecture or lab, but to truly experience, explore and reflect on engineering concepts, students need access to build and test the concepts using hardware and software tools. Many of the self-study tasks indicated here involve the use of software only. One barrier facing educators and students is accessibility to these tools and technology to explore the fundamentals of engineering in self-study. Traditionally, these tools are either too expensive for a school to afford for each student and/or the size limits the use and accessibility of the system.

For many engineering concepts, students get their experiences through measurement of phenomena and being able to apply theory to these measurements. It is not feasible to provide every student with the equipment featured in undergraduate labs to create their own lab at home. But if students could be given access to hardware and software instrumentation tools that would allow them to create their own measurement experiments outside of the lab,
educators would be able to increase the number of hours for each course dedicated to problem-based or project-based learning.

3. STUDENT OWNED INSTRUMENTATION

To extend hands-on learning outside of the lab environment for a student, National Instruments collaborated with engineering educators incorporating a hands-on component as part of their instruction from 16 universities. Through the collaboration, requirements were determined for a portable student personal instrumentation device (Walters, 2010).

Released in 2010, NI myDAQ is an instrumentation platform designed for students. The device is a low-cost portable data acquisition (DAQ) platform that gives students the ability to measure and analyse live signals on a computer. The hardware instrument includes eight software instruments, based on LabVIEW, to control the NI myDAQ device, providing the functionality of a suite of common laboratory instruments, including a digital multimeter (DMM), oscilloscope and function generator (shown below in Figure 1). Students can access all the ready-to-run software instruments to perform experiments and exercises.

In education, National Instruments also provides a lab-ready partner product in the form of NI ELVIS, adopted by many universities worldwide. The NI ELVIS and NI myDAQ platform share a common software experience, and when used by students in lab and at home, it gives a complementary and consistent approach to taking measurements and experience of real world signals.

![NI MYDAQ HARDWARE](image)

FIGURE 1: NI MYDAQ HARDWARE

In industry, National Instruments also has considerable experience of developing advanced data acquisition devices based on standard PC technologies. NI myDAQ is based on this same data acquisition platform, providing high-performance I/O, industry-leading technologies, and software-driven productivity gains designed for engineers and scientists.

When combined with NI LabVIEW, the NI myDAQ creates a hands-on learning solution for many core concepts in engineering curriculum. Using the graphical programming environment, educators and/or students can create their own measurement and automation
applications to explore a variety of concepts, such as analogue circuits, sensors and signals, and systems.

With the introduction of a relevant ‘plant’ for them to explore, students can also tackle wider engineering challenges to understand engineering fundamentals. An example of such a plant is shown in Figure 2, a small scale power generation plant, which can be used to demonstrate concepts such as energy monitoring and conservation, and smart grids. The system represents the mixture of both fossil fuels, represented by a motor, and renewable power sources, using a solar panel. Students can monitor and control how much energy is provided by each of the power sources based on availability and demand, demonstrated by varying the load of the houses.

Students can also be inspired to create their own systems, to explore engineering concepts through challenges which are relevant to them.

3.1 Case Study: The University of Manchester

Dr Danielle George, Director of Teaching and Learning, School of Electronic and Electrical Engineering at The University of Manchester, along with colleagues in the School, have been using the NI ELVIS platform for lab-based experiments in a wide variety of subjects, including Electronic Circuit Design, Digital System Design and Control Systems for some time. The introduction of NI ELVIS into their curriculum came about after a review of practical work undertaken by students in response to low student satisfaction surveys (NSS).

Upon introduction, the University noticed immediate improvement in student engagement; the combination and usability of hardware and software made students more comfortable with their first labs, allowing them to focus more on applying the concepts they were learning than on figuring out how to use equipment, ultimately giving them a deeper understanding of the connection between theory, simulation and experiments. After just one year, the 2010 NSS reflected the results of the extensive school-wide effort, including the changes to the laboratory experience: the overall student satisfaction score increased from 67% to 98%.

In an effort of continuous improvement and maintaining the high standards already achieved, from 2011, all incoming first year students will be provided with an NI myDAQ to further enhance their learning experiences, and encourage them to continue their experimentation outside of their classes.
Learning materials have been developed by students at the university, providing incoming students with materials to encourage them to further explore concepts covered in their lab sessions. The students developing the materials were easily able to identify concepts most commonly struggled with and designed exercises to allow students to experiment at a pace and in an environment that could be personal to each student. Early feedback and assessment shows increased student engagement and familiarisation with key measurement and instrumentation skills required in each laboratory session.

3.2 Case Study: University of Leeds

The University of Leeds runs a Product Design course in the School of Mechanical Engineering. This course combines elements of design and engineering to produce creative and skilled designers who understand both aesthetics and technology. The first and second years of the course are divided into three broad subject areas: technology modules; design awareness modules; and design studio modules.

In the technology modules, amongst other things, students are taught concepts of electronic engineering to enable them to create designs that are both efficient and effective. Students undertaking the Product Design course are not required to have a background in Maths or Physics, as is typical in Electronic or Mechanical Engineering courses.

As such, the electronic engineering modules can often be the first exposure students will have to electronics. Creating engaging content that provides students with the understanding to go on and create products can prove challenging. In 2011, Dr David Keeling introduced the NI myDAQ into two modules: Basic Electronics for Product Design in Year One; and Advanced Electronics for Product Design in Year Two.

In Basic Electronics for Product Design, students use the NI myDAQ to analyse simple circuits to understand common electronic components, before using their electronics knowledge to design and build a circuit to act as a games controller (Figure 3 below shows an example of such work), interfaced through the NI myDAQ to a simple game designed in LabVIEW. Students use components, such as potentiometers and force sensors, to act as human input devices.

![FIGURE 3: GAMES CONTROLLER CIRCUIT](image)
In Advanced Electronics for Product Design, students are tasked with learning more about the software side of electronic product design, and use the NI myDAQ with LabVIEW to develop both the hardware and software elements of a game or similar product.

Student feedback so far has shown that the students are engaged and challenged by these modules, and will be equipped to tackle more complex product design in their project-based modules in years three and four.

4. NEXT STEPS

NI myDAQ has been designed to provide educators and students with an opportunity to enhance hands-on learning experiences, by enabling their continuation outside of the lab. More work is needed in collaboration with industry and academia to develop a complete ecosystem for students to explore engineering concepts. One area of cost that has not been addressed here is the cost of academics’ time to develop engaging lab ideas and create new course materials to support these.

National Instruments is creating a community (National Instruments 2012a, 2012b) to allow educators and students to share their completed projects and curriculum. Once students have grasped the basic principles of using software and hardware like NI LabVIEW and NI myDAQ through guided tasks aimed, for example, at learning electronic engineering principles (Doering 2010), students can be inspired to create their own open-ended experiential learning programmes, through exploring concepts which are relevant and interesting to them (Leverett 2011, National Instruments 2012b). Sharing these projects, and inspiring others to do the same through social network style community systems, speaks to students on a different level to their traditional more structured learning experienced in the classroom.

We have discussed a number of concept areas that could be covered using these tools, including analogue and digital circuits, power electronics and control, but there are still challenges, based on the capabilities of the tools, to cover concepts taught in Communications or Embedded Systems Design courses. NI is continuing to work with industry and academia to leverage commercial technologies, and bring this capability to students both inside and outside the classroom. A recent approach taken is to introduce low cost technologies, based on the same software experience outlined in this paper, for exploring RF and communications principles. NI USRP offers a unique opportunity to experiment with real world signals in courses covering these areas. (National Instruments 2012c)

5. CONCLUSION

As previous research has demonstrated, there is a need for more hands-on experiential learning in engineering programmes. We have highlighted the large number of hours dedicated in most engineering modules for self-study, and identified an opportunity to
provide students with more hands-on learning experiences during these hours. Providing students with their own tools, and inspiration to experiment in these self-study hours, would alleviate the need to provide access to overstretched labs outside of scheduled teaching hours.

Through the introduction of NI myDAQ, and its supporting community, we believe that we have made progress in helping educators to fill this gap. We have seen from a number of programmes how this device can be used to enhance engineering education, and improve students’ experiential learning. Further work is still needed to complete the eco-system, and we encourage collaboration between academia and industry to do this.

6. REFERENCES


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