Abstract—There has been a lot of emphasis placed on providing hands-on project based learning in engineering education. A lot of these initiatives have also been successful in creating an environment where the student goes beyond theory and incorporates real-world signals in the experiments. However, there is still a major gap in being able to sustain this kind of excitement—being able to provide an immersive hands-on learning experience throughout the tenure of a student’s time in engineering. This gap becomes apparent when we consider that a student only spends one-fifths of their time in the lab as compared to a staggering three-fifths of their time doing their homework. However today, apart from some grass root efforts there is not much emphasis to introduce hands-on project based learning as part of a student’s homework experience—primarily because of the lack of affordable technologies. In this paper, we will explore Project based learning advances in both undergraduate engineering classes like introduction to engineering and senior or capstone design as well as the pipeline that feeds into the university space, the high school programs. We will then make the case for need for project based learning in the dorm room, and what the requirements are to enable educators to make experiments scalable to the dorm room. We will also look at an implementation from Georgia Tech and the lessons learned from their experiment as well as look at some technologies that lend themselves to dorm-room based experiments. (Abstract)

Keywords—student-ownership, project-based learning, dorm-room, myDAQ, homeworks, interactive learning, hands-on PBL

I. INTRODUCTION

The past decade has seen significant advances in incorporating hands-on project based learning in engineering education and there is ample literature to support the same[1-3]. These experiments have also been documented to show increases in retention rates in mid-to-upper level courses in engineering education [4, 5]. In order to continue addressing the student engagement issue, we have to understand where students spend their time during their typical engineering tenure. Interactions with educators indicate that students spend time in four major areas during their tenure in engineering – lectures, lab, project and homeworks. As literature indicates, a lot of effort has been put into making labs and projects more relevant to real-world and a very open hands-on format. If one examines the teacher student interaction today from a lecture based class, it could largely be represented as figure 1

![Pedagogical model as it exists today](image)

Figure 1. Pedagogical model as it exists today

The current model presents can help us draw some interesting conclusions:

- It is theoretically possible to keep the excitement level of the student high by making lectures more interactive
- It is equally important to focus on what the student does after the lecture, to make sure that they do not lose interest

As industry partners to education we have seen two areas where educators are taking steps to address these opportunities in lecture based classes:

1. Evolve the freshmen/introduction to engineering courses to include hands-on project based learning experiments
2. Provide continuity in the hands-on approaches being provided in the lab environment to the lectures and homeworks

These trends are a result of the improvements that are being made at both the upper level engineering courses such as capstone design that demand students to have experience with hands-on experimentation as well as in the high-school space with robotics competitions such as FIRST robotics [6,7,8,9] and project based learning systems such as Project Lead the Way[10,11]
II. HIGH SCHOOL PROGRAMS – A QUICK REVIEW

In order to help increase enrollment in engineering, several universities, organizations, and corporations including National Instruments have recognized that it is important to create excitement in the high school space about engineering education. We highlight two such organizations that are pushing the envelope when it comes to bringing hands-on project-based learning to the high school students.

A. FIRST Robotics

FIRST [6], founded by Dean Kamen is a program that aims to position scientists and engineers as heroes that should be celebrated. To achieve this goal, FIRST holds a worldwide robotics competition with student teams building, programming, debugging and finally, competing with their robots on a common challenge – all in 6 weeks time. Figure 3 shows a student from FIRST working on a robot system.

![Figure 3. A high school student working on a robot at the FIRST championship](image)

To give an estimate of the complex system that the students are working with, the robot system is an FPGA based real-time system that has multiple I/O from Analog and digital I/O to CAN and serial interfaces priming the students on project-based learning.

B. Project Lead the Way

Project Lead the Way is another outreach program that as the name suggests has built an entire set of courses for high schools that are based on open-ended projects. Figure 4 shows students working on a biomedical engineering project.

![Figure 4. Example of Project Lead the Way Biomedical Course](image)

Project Lead the Way has courses that cover areas from manufacturing, digital electronics, design as well as biomedical engineering. For a full list of syllabi and curriculum, readers can visit [11].

FIRST robotics and Project Lead the Way are two of the many outreach programs in the high school space. Readers can find these or similar programs around most university and high school systems. With such programs, there is a steady stream of students who are conversant with the concept of hands-on project-based learning. The question now becomes “how do we continue the same level of engagement as we introduce them to engineering?” The challenge begins with the first course the student takes in engineering, Introduction to Engineering.

III. INNOVATIONS IN INTRODUCTION TO ENGINEERING

Almost all Top 50 engineering programs ranked by US News have some kind of introduction to engineering – some programs call it “Principles of Engineering” or “Introduction to Programming”, but the goal of this class is the same everywhere – one semester introduction to engineering concepts and hopefully engage students to continue pursuing engineering as a career. Hence it is critical to have an engaging, interactive, hands-on environment in this class to continue to tap into the excitement of the newly enrolled engineering students.

To illustrate the advances that educators have made in this area, let us take a look at one engineering program that has revamped their introduction to engineering classes – Texas A & M University. The Texas A & M introduction to engineering class is large with over 1000 students enrolled. They have three tracks, one of which has around 900 students and the students come from various engineering departments – Mechanical, biomedical, chemical, aerospace constituting the majority of the enrollments. In its previous incarnation, the class was a theory-only lecture based class. However, Dr. Arun Srinivasa and Dr. Don Maxwell took a different approach [12] to this class and introduced real-world challenges to teach core engineering concepts such as statics and dynamics with a student affordable platform with LEGO MINDSTORMS NXT®.
The class now involves open-ended challenges with real-world constraints and involves students performing tasks such as path planning and obstacle avoidance as shown in Figure 5. Another example of a similar implementation is the freshmen introduction to ECE design class at Georgia Tech taught by Dr. Doug Williams et al. Readers can get more information about this class at [13].

Making introduction to engineering courses and other theory courses hands-on and interactive is critical to continue engaging student – however, that is merely half the battle. As Figure 1 indicates, the other half of the challenge is addressing the homework/dorm room component.

IV. INNOVATION IN HOMEWORK EXPERIMENTS

Based on the system in Figure 1, it is clear that there needs to be a focus on how to enhance a student’s experience outside the lecture. To understand the needs of this dorm-room space better from an instrumentation perspective (the authors primary area of expertise), we performed a survey of professors from 16 universities. All the 16 universities were from the US Top 50 engineering programs as ranked by U.S. News [14]. Our choice of universities was limited by bandwidth of our own personnel. All professors we interviewed for the survey were involved in teaching a lecture course that included the possibility of some form of hands-on component. The survey itself was qualitative with questions such as:

- What are your top requirements for a student-owned homework device?
- Which is your primary concern that we need to keep in mind while developing such a product?
- How do you see students getting help on this product?
- What are the features you would like to see in a student-owned device?
- What classes can be made interactive with such a device?

Our results are summarized in Table 1 below:

<table>
<thead>
<tr>
<th>Question</th>
<th>Majority Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top requirements</td>
<td><strong>Basic Instrumentation:</strong> Oscilloscope, DMM, FGen</td>
</tr>
<tr>
<td></td>
<td><strong>Student capable:</strong> Rugged, Bus-powered</td>
</tr>
<tr>
<td></td>
<td><strong>Usability:</strong> Standard connectors, Easy-to-program, ESD protected</td>
</tr>
<tr>
<td>Primary Concern</td>
<td>Cost – must be low ($150-200) – All respondents had this as a concern</td>
</tr>
<tr>
<td>Help</td>
<td>Online preferred, no printed manuals</td>
</tr>
<tr>
<td>Like to have</td>
<td>Touch screen, Audio/ipod inputs, External memory support, wall power support for autonomous operation</td>
</tr>
<tr>
<td>Classes possible</td>
<td>Circuits, Digital electronics, sensors, capstone design and basic control theory</td>
</tr>
</tbody>
</table>

Table 1. Results of the qualitative survey for student instrumentation device

Parallel to our research into understanding what the needs are of a student-owned instrumentation device for dorm room use, Prof. Bonnie Ferri from Georgia Tech as part of the TESSAL research center (Teaching Enhancement through Small-Scale Affordable Labs) [15] performed a survey to compare the needs of experiments a laboratory Vs at-home application [16]. This survey is shown in Table 2 for the readers reference.
In an indepth review of the entire experiment as well as the survey process and outcomes we encourage readers to [16,19,20,21]. It can be seen that this survey echoes the two themes consistent with ours:

- Cost
- Ruggedness

V. SURVEY OF TOOLS TO AID INTERACTIVE CLASSES AND HOMEWORKS

Based on both the work by TESSAL group as well as our own survey, we investigated the options available for educators to design both at-home experiments as well as create interactive in-class experiments.

A. Software

Our survey found that students could gain access to most engineering software either for free through the university licensing system or for a very low cost. Our survey also found that both Windows and Mac OS support is ideal and Windows support is a must. Linux support was not seen as a hard requirement. Our survey indicated that for any software that is being given to students for dorm room use, an online support community is important because of unavailability of TAs 24/7

B. Hardware

We found a number of hardware for control/design. The most common hardware we found used was the LEGO MINDSTORMS NXT® shown in figure 6.

Figure 6. Main Brick of LEGO MINDSTORMS NXT®

Anecdotal reasons for the choice for the LEGO MINDSTORMS NXT brick included that it had a wide variety of sensors such as light sensor, color sensor, ultrasonic sensor, touch sensor and easy connectivity to high quality motors. Other reasons included ruggedness of the platform, ease-of-programming as well as its low cost and easy availability. At the time of writing this paper, the LEGO system cost about USD 250 to acquire.

Other hardware options that were cited were the Stellaris Cortex M-3 ARM board[17] as well as the Arduino[18]

The authors found that while there were a lot of control/design hardware options, there were not many student-affordable instrumentation options available that met the needs of the educators surveyed

VI. NEXT STEPS – DESIGNING AND GATHERING FEEDBACK ON NI MYDAQ

With our organization’s expertise being instrumentation, and based on feedback from our survey, we have begun to design a student-affordable instrumentation device that they can take to their dorm room, use it for various courses including circuits and capstone design. Figure 7 shows an early schematic for the NI myDAQ device we are in the process of designing.

Figure 7. NI myDAQ student instrumentation device preliminary schematic

Our design constraints include the results from our survey presented in Table 1. We believe that we can meet most of the top requirements as well as the audio support. We cannot however meet some of the “like-to-have” requirements because of cost to build – the most notable feature we cannot add is the touch screen.

We hope to make the device satisfy the ease-of-use component by making it rugged as well as targeted with LabVIEW, our graphical programming software. Currently we are testing early prototypes in classroom setting working with professors who participated in our survey as well as a select few others who had expressed interest in working on a dorm-room based teaching model. The results of this study will be published in a future paper. We also would like to invite readers to contact us if they are interested in participating in this study. We expect the first version of this device to be available for broad based use later this year.

VII. CONCLUSION

In this paper we identify a growing trend among educators to include hands-on project based learning at all levels of engineering education, from the introduction to engineering courses to capstone design. We also analyzed that a typical engineering student spends over 50% of his or her time doing...
homeworks, while only 17% of their time in labs thus creating a need to make homeworks and lectures more interactive and project based. Independent surveys performed by the TESSAL group at Georgia Tech and us helped identify the requirements for hands-on project based learning tools for homeworks. We also found that while there are several alternatives for design/control hardware that students can afford, there is no clear instrumentation device that is affordable by students. Based on this feedback, we have begun the process of designing a student instrumentation device, which we call NI myDAQ specifically for student-ownership. We are testing out early prototypes at select universities and invite the readers who are interested in helping us with this process to contact us.

REFERENCES
[10] Project Lead the Way program http://beta.pltw.org/