HARDWARE SKILLS FOR HARDWARE ENGINEERS

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Abstract –Electrical engineering students at the University of Waterloo require opportunities to develop hardware workflow skills. For example, creating, populating, and debugging printed circuit boards. Students may be fortunate enough to gain these skills on co-op work terms, but there is no structured on-campus opportunity to learn these topics. These workflows cannot be added to the existing curriculum without displacing other valuable learning opportunities. An optional “Embedded μ C PCB Activity” is being developed to fill this gap. The Kolb learning cycle and project-based learning principles have been applied in its creation, and the Kirkpatrick Model of Training Evaluation is used as a framework to assess student reaction and learning. The activity was first trialled and found unsuccessful in 2017 but is now prepared to undergo another trial due to iterative improvement.

Keywords: Project-Based Learning, Kolb Learning Styles, Experiential Learning

1. INTRODUCTION

Electrical and Computer Engineering (ECE) is an expansive area, spanning quantum, materials, hardware, embedded, software, robotics, and control systems. This extent makes it very difficult to strike the right curricular balance between breadth versus depth, and concepts versus skills. Students in the Department of Electrical and Computer Engineering at the University of Waterloo benefit from a well-established co-op program, but their co-op terms cannot be expected to fill all the relevant skill gaps. This is especially true for students interested in hardware development because of the supply and demand of jobs: there are significantly more software co-op jobs available than hardware however, the interest in hardware jobs is still high. Further, hardware workflows are too complicated, specialized, and time-consuming to justify their inclusion into the core undergraduate curriculum.

Students take core and elective circuits and embedded programming courses throughout the undergraduate program. The embedded programming labs result in resume-ready skills, but the circuits labs do not. Indeed, students do create complex analog amplifier circuits on a breadboard, but they do not progress to a more refined

prototype stage. They do not need to address constraints concerning the power supply, physical interface, component choice, mechanical design, thermal management, or manufacturability. Additionally, completing a full electronics prototype workflow would not fit well into current course structures.

2. OPT-IN PROJECTS

To address this skills gap, optional projects have been created that supplement the core curriculum, and students can opt-in based on interest. The Kirkpatrick Model of Training Evaluation [1][2][3] has previously been used to assess ECE learning activities [4], and was adopted as a framework for evaluation. The projects use experiential learning principles, which can be more impactful than standard lectures and labs [5]. Further, project-based learning principles have been shown to improve student learning [6]. The projects pair instructor-led in-class design with a hands-on project, with the goal of moving students through the entire Kolb learning cycle [7][8]. Traditional lectures and labs tend to move students within two or three Kolb quadrants but rarely traverse the full cycle. So, a concerted effort was made to embed these principles into the project flow.

Fig. 1 – Student self-assessment of hardware workflows before and after the Learn to Solder sessions. 200B and 300B refer to the 2B and 3B courses used to host the sessions, respectively. Students chose from levels on a rubric consisting of Beginning, Developing, Accomplished, and Exemplary. Accomplished and Exemplary constitute “meeting expectations”.

Two existing projects, the Learn to Solder session and the Communications Challenge, have resulted in positive reaction and learning as assessed by the Kirkpatrick Model. Student reaction has been positive for all the project offerings, and Fig. 1 shows an example of pre-post indirect (self) assessment of learning taken from the Learn to Solder sessions offered in the Fall 2015 term. Previous work [9] shows a positive correlation between direct- and self-assessment, and further confirms that learning occurred during the project.

2.1. Embedded μ C PCB Activity

Given the success of previous projects, we designed an optional activity called the “Embedded μ C PCB Activity,” to strengthen the skill sets of hardware-oriented ECE students. The goal is to use industry standard workflows to produce a custom embedded microcontroller (μ C) printed circuit board (PCB) assembly that can be used for other projects. Students can add the schematics and layouts to their portfolio and bring the final product to their interviews. Students can also use the assembly to practice embedded programming, further strengthening their hardware skillset.

Students create schematics and layouts given a Bill of Materials. Their schematics and layouts undergo a design review with all the participants. Students submit layouts for fabrication overseas. When the fabricated PCBs return, students use stencils to apply paste, manually place the components, and reflow the boards. They hand-solder any through-hole components. Finally, they do board bring-up, debug any issues, and implement a test program.

The Embedded μ C PCB Activity was piloted in the Spring 2017 term. Students used CircuitMaker (a free cloud-based version of Altium) as a PCB CAD tool. They were walked through the design of a 4-layer surface-mount PCB that included a TI MSP430F5224 and 128 x 32 LED display controlled via serial peripheral interface (SPI). The project was not completed because CircuitMaker was only available on Windows, however many students had Macs.

In Fall 2017 and Winter 2018, EAGLE and DipTrace were investigated as alternative CAD tools as both programs are available on Windows and Mac, and both offer a free version. Finally, DipTrace was selected over EAGLE because it was found to have a more intuitive workflow. Two undergraduate students developed a library of necessary components for schematic and layout.

3. NEXT STEPS

We are piloting the revised activity in the Spring 2018 term. We will be measuring student reaction and learning with pre-post testing and surveying. Based on the results, we will continue to improve the activity iteratively so that it remains aligned with the needs and interests of

hardware-focused students. We are also investigating whether it should remain as an individual activity, or become a group activity. Research indicates that group work in similar activities can result in more significant learning [10]. We intend to make the project publicly available.

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