Evaluation on Teaching Embedded System with Portable Labs in a Box

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ABSTRACT
The rapid growth of embedded systems results in a shortage of professionals for embedded software development. However, embedded system education is not well represented in current Computer Science (CS) academic programs. Due to budget cuts and resource limit, it becomes harder for higher education institutions to maintain traditional laboratory than ever before. In this paper we present our implementation of embedded system courseware with a carry-on lab in a box (a very affordable 8051 microcontroller development kit) which can be conducted anywhere and at any time. It can be implemented on line, partial on line, or in class room. Its portability allows students to work on the labs at anywhere anytime. The evaluation has shown that hands-on lab oriented curricula well engage students in learning and prepare our graduates directly into the nation’s workforce.

Keywords
Embedded, portable, real time, engineering

1. INTRODUCTION
Many schools realize that we need to enhance embedded systems education to meet the rapidly growing demands in industry. Unfortunately, existing laboratories generally require significant investment in resources. Due to limited resources including budget, equipment, lab space, or faculty expertise, many schools teach such courses without hands-on lab practices or with antiquated equipment which drastically hinders student learning. Existing embedded systems instruction relies on significant investment in lab resources and high requirement for instructor’s expertise. To overcome these difficulties, we have developed an online embedded software courseware with hands-on labs in an inexpensive portable box. The portable and modular design of this courseware provides a “ready-to-adopt” model for broadening embedded system education. This courseware is especially suitable for the universities/colleges that have the need of embedded system education but are constrained by limited financial budget, scarce dedicated staff and faculty and lab facilities.

2. MODULAR AND PORTABLE LABWARE
The developed courseware adopts a modular structure that organizes the courseware into a sequence of teaching modules. Each module includes lecture notes, PPTs, review questions, hands-on laboratory practices, and assignments. It also provides portable real labs based on a popular MCU development kit. All learning materials and lab manual videos are posted online. Because of the modular design, the courseware is easy to be integrated in other undergraduate computing courses. Meanwhile, the hardware needed to teach these modules is minimized due to the portable labs. We have used these modules in an online embedded software development course and a CS capstone course. We plan to integrate the course in other courses such as software engineering, computer organization, and operating systems. All hands-on labs are developed and implemented using the portable, supercharged 8051 MCU based C8051F005DK development kit from Silicon Laboratories Inc. which comes with necessary I/O, serial ports, and a basic RTOS. It costs at an average textbook price. The kit comes with an Integrated Keil C51 IDE which provides students with the hand-on opportunity to work with real-world embedded system projects instead of simulation only.

This course is designed with a particular focus on the software design and development of embedded system rather than the hardware design although students will be exposed to hardware design especially in the I/O peripheral layouts and interaction controls.

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### Design criteria
- Microcontroller, I/O Ports, Memory, SFR, Interrupts
- C51, Assembly for 805

### Concurrency
- RTOS based multi-tasking scheduling, Round-robin
- Preemptive priority, Sync and Async tasking

### Serial communications
- Communication modes, UART, serial Port I/O, Handshaking, Baud Rate

### Software engineering SDLC

### 3. EVALUATION

This class becomes one of the most popular elective classes in CS and SE curriculum since we offered it. The student feedback is always overwhelming positive. Many students said in the class survey that they had great opportunities to practice the theory and abstraction to practical application; to integrate their knowledge learn in the CS and SE programs to solve real-world problems; to co-design and develop software with microcontrollers to produce a real world embedded systems on their own. Students enjoyed in working with development embedded software in cross-platform environment. One of the contributions of the designed labs and equipments is the inexpensive, completeness, and feasibility for any schools with limited financial recourses. It also provides a model for any instructors to start up an embedded software course with supported labs. The following chart shows the feedback from students.

Q1. I like this PEARL online courseware
Q2. The labs in a box provides hands-on experience on embedded system design.
Q3. The online instructional materials help me understand concepts better.
Q4. The online lab guidelines (video, demo) help me work on labs and assignments.
Q5. The textbook has a good fit to the courseware.

There are five score survey choices for each evaluation question:
- Strongly agree (5)
- Agree (4)
- Neutral (3)
- Disagree (2)
- Strongly Disagree (1)

The YesPercentage bar represents the choices of “Strongly agree” and “Agree”;
The NoPercentage bar represents the choices of “Strongly Disagree” and “Disagree”;
The ZeroPercentage bar represents the choices of “Neutral”. The student survey chart shows a very positive learning assessment.

### 4. CONCLUSION

This paper presents a new pedagogical teaching and learning model for improving student learning in embedded system and preparing students for tomorrow’s embedded system workforce. Most students enjoyed what they learned in the new courseware. In particular, students favor the hands-on portable labs. Students were excited with their creativity opportunity of working on the embedded projects with the kit.

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