An Open Mobile Platform Approach to Integrating Active Learning Across the EE/CE/ICT Engineering Curriculum

Mihir K. Ravel, Mark Somerville
Franklin W. Olin College of Engineering
1000 Olin Way, Needham, MA U.S.A. 02492
mihir.ravel@olin.edu, mark.somerville@olin.edu

Gunar Schirner, David Kaeli
Northeastern University, Dept. of ECE
360 Huntington Ave., Boston, MA U.S.A 02115
schirner@ece.neu.edu, kaeli@ece.neu.edu

Abstract- **This paper presents an open hardware/software mobile platform approach for supporting innovations in electrical and computer engineering education. The highly-configurable platform model supports timely linking of theory with practice, and integration of active learning across classroom to lab to home.**

I. INTRODUCTION

Much activity has taken place in the last decade [1, 2, 3] using applications development on mobile phones as a method for teaching modern computer science. The attractiveness of this approach includes an easily seen relevance to society, exposure to modern technologies, and the important motivational factor of being "cool and fun". The drawback of this approach for EE/ECE/ICT engineering education is that the student's exposure is often at a high level of software highly abstracted from the underlying computing, communications, and sensing concepts and technologies.

This paper outlines our experiences with active learning in electrical and computer engineering education using an open mobile platform capable of supporting a broad range of EE/ECE/ICT concepts across the learning continuum from classroom to lab to home. The approach supports investigation of several learning objectives including integration across the engineering curriculum, connecting theory to practice, enhancing student engagement and self-direction, increasing students' system-thinking abilities, and most importantly, facilitating – rather than dictating – pedagogical change.

Our work has been done at two complementary institutions, Northeastern University (NEU) and Franklin. W. Olin College of Engineering (Olin), which are in close proximity yet span a very wide educational spectrum. Northeastern is an urban research university with large undergraduate and graduate bodies. The student body at NEU is quite diverse, and in particular includes a large population of non-traditional students. NEU provides a realistic test bed for investigating pedagogical models in a research university environment. Olin College is a relatively new undergraduate-only engineering college (students were first admitted in 2002). During its existence, Olin has established a reputation for project-based education and for approaches that increase students' creativity and entrepreneurial skills. Due to a flexible curricular structure, it is relatively easy to test new course and project ideas at Olin. The mobile platform approach has been piloted in classes at both schools, and this paper reports on our experiences and future directions with expanding this model.

II. EDUCATIONAL CONTEXT

Over the last twenty years, global changes have triggered calls for systemic changes in engineering education, including increasing students' capacity for life-long learning, enhancing abilities to engage in system-level thinking, and incorporating more engineering practice and design throughout the curriculum [4,5]. Despite these pressures, change in engineering education remains a very slow process. Most engineering coursework is still structured around a classroom lecture, and practice is confined to a separate laboratory. This provides little opportunity for students to immediately apply theory to practice, and often leads to low student engagement, low retention of engineering theory, and little understanding of what engineers actually do. A promising model for effecting change in engineering education is hinted at by Traylor et al.: one can *start with a technology that facilitates and inspires change*. Traylor proposes the concept of a "Platform for Learning" – a common unifying object that weaves the student experience across multiple courses and projects[6]. As Traylor notes, "using a common platform throughout a degree program [can enhance] the integration of knowledge. The platform provides the conceptual 'glue' ... Interactions between topics become clear." Given the success of platforms for accelerating innovation in industry, our interest has been in exploring platform approaches specifically for integrating learning across the curriculum and across the daily learning cycle.

III. GUIDELINES FOR ACTIVE LEARNING PLATFORMS

A number of educational institutions such as OSU, RPI, and Virginia Tech are exploring platform approaches for bringing innovative learning into the curriculum while also achieving significant cost, efficiency, and space benefits [7,8,9]. Although the use of platforms is recent in academics, it is a well established practice in industry where platforms have been the basis of product development for several decades [10,11,12,13]. Yet platforms inherently have a tradeoff between generality and utility, as too simple enables only a limited scope of use, while too complex leads to excessive costs and learning curves, so a platform approach has to be tailored to the needs of the application domain. As A. Sangiovanni-Vincentelli et.al. have observed in their landmark paper [11] on Platform-based Design: "Platforms have become an important concept in the design of electronic systems … The main challenges are to distill the essence of the method, to

formalize it and to provide a framework to support its use in areas that go beyond the original domain of application."

In 2006 an exploratory education project was initiated, by author Ravel and M. McDermott at the U. of Texas-Austin, to see if an open system-design platform could be developed with enough generality to support experiential learning across typical EE/ECE/ICT curricula [14]. Needs and best practices were gathered from faculty in the US, Europe, and Asia to help define a system that would be globally relevant. The focus was courses that would be likely to benefit from a design-centric active learning pedagogy for both studio, lab, and project use. In observing faculty that had built their own custom platforms, several attributes emerged for a cross-curriculum platform:

- Ability to blend both open and commercial software tools
- Modular hardware design with user expandability
- Heterogeneous technology to support broad domain coverage and for exploring partitioning and tradeoffs
- Industrial strength capability to enable student exposure to real-life components and practices
- Ideally desktop size to allow both class and lab usage
- Cost less than or equal to typical lab bench setups

An initial prototype was developed in 2007 (Gen1) that was a modular architecture consisting of multiple technology options for each of the basic system elements of communications, computing, and real-world interfaces [14]. This system has been piloted globally in large research universities (U. of Texas-Austin, U. of Wisconsin-Madison, IIT-Madras, IISC) and medium (U. of Novi Sad) to small colleges (IIIT Bangalore, Olin College of Engineering), across 2nd year undergraduate to 2nd year graduate level courses [15, 16]. There were several lessons learned from the Gen1 pilots:

- It is possible to support a broad range of courses
- Common SW tools inspired spontaneous team work sessions - mostly outside the lab
- A small set of elements provided the most value
- Enabling partitioning and tradeoff exercises fostered system thinking skills
- Student engagement is not as high in a lab-centric model - many students wanted units to work outside the lab

IV. MOBILE PLATFORM OBJECTIVES

The lessons from the Gen1 "lab-centric active learning" experience were used to guide the "personal active learning" mobile platform approach described in this paper. The Gen1 experience targeted courses at multiple institutions to investigate applicability across typical lecture/lab settings, so the the next logical step was to investigate active learning beyond the lab and classroom. We defined several properties for a platform aimed at personal learning:

- Portable "look and feel" relevant to modern gadgets
- Highly tuned towards Human Interactivity
- Sufficient performance/resources for real-world projects
- Sufficient variety for partitioning and tradeoff exercises

Key goals were to have a simplified architecture in a portable form factor with sufficient performance to engage students' imaginations and enough flexibility to support teachers' needs.

V. MOBILE PLATFORM SYSTEM ARCHITECTURE

The Gen2 mobile active learning platform contains the basic modular elements of communications, computing, and physical world interfaces. The system is comprised of an open software environment and a modular mobile hardware module (Fig. 1).

The software environment is a standardized Fedora Linux system preconfigured with all tools, libraries, and paths required for developing applications on the mobile platform hardware. This customized Linux distribution builds on top of the open Fedora Electronics Lab (FEL) Linux community aimed at encouraging open electronics and computing design [17]. We have added to the base FEL distribution additional elements for targeting the computing and logic fabrics on the mobile hardware. The design environment can be used from a "live" USB flash-drive or installed on a real or virtual PC.
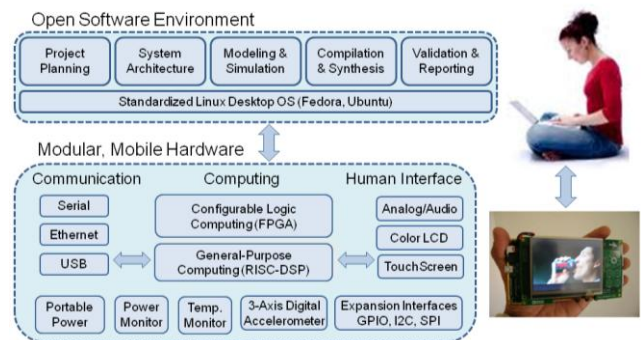

Figure 1. Mobile Platform Architecture

The Gen2 mobile hardware platform provides heterogeneous computing fabrics of a 600 MHz RISC processor and a Field Programmable Gate Array (FPGA). Together they span a range of processing from low-level logic programming using assembly language and Verilog/VHDL HDLs, to embedded programming in C/C++, and up to high level Python on the platform's embedded Linux operating system. The mobile platform provides a set of physical world interfaces suitable for circuit/systems exercises: audio I/O, 3-axis accelerometer, power, and temperature sensors. The networking interfaces (USB, Ethernet, Serial) allow distributed networking and communications systems to be explored. An engaging human interface with color LCD and touch input gives the feel of real-world electronic products familiar to students, and easy integration of the system with imagers/webcameras allows exploration of vision/imaging concepts. The architecture is designed for user expandability through high speed parallel IOs and standard serial interfaces (SPI, I2C, UART). This architecture allows for courses to use end-to-end examples, such as image processing loops (video recording, processing, output), signal processing of audio data, and machine control. Naturally no platform can cover all course domains, so the architectural emphasis is to allow user customization tailored to the unique teaching needs. We see the platform approach as an enabler rather than a fixed solution, and expect the system has sufficient scalability in performance and peripheral expansion to support learning experiments from introductory engineering up to advanced elective topics.

VI. PHASED PEDAGOGICAL DEPLOYMENT

To investigate the application of the open mobile platform model to typical EE/ECE/ICT curricula, we have followed a two step sequence. The first phase objective was to gain an understanding of the student usage and suitability for wider use across the curriculum. Based on Phase 1, a Phase 2 broader deployment is being developed to investigate integration of active learning across the curriculum and across daily usage.

The Phase 1 trials of the mobile platform in 2010-2011 were in two widely different course settings at NEU and Olin. The Olin trial was in a loosely-structured and low-contact model in a small college setting, and the NEU trial was in a highly-structured, high-contact large department setting. Our observations follow below.

A. Olin - Embedded Design Project-based Seminar

At Olin the goal was to explore the mobile platform approach in a personal use model over a wide range of student capability. An experimental for-credit project-based seminar was developed with a once per week two hour studio-type lecture providing a framework for independent student exercises and project work. The students typically worked on projects in solo or dual-person teams. The students spanned 2nd year to 4th year undergraduates with basic software skills in C programming, and very modest hardware familiarity at the level of simple op-amp circuits and 8-bit microcontrollers. Each team was provided with a mobile platform for studio exercises during lecture and for personal use on their own time.

The instructional model can be described as a systems oriented "top-down" approach starting with the students' selection of project ideas and forming teams. The teams defined initial system architectures and specifications, and then built simulation models and high level software prototypes of potential solutions. After this modeling phase the students progressed "downwards" towards the hardware using the mobile platform as a rapid prototyping tool for trying real-time implementations. The mobile platform provided powerful local processing and a familiar programming environment for executing real-time implementations (embedded Linux operating system with C and Python). This approach of "porting" a desktop software model into real-time hardware proved very successful and all students were able to move from desktop model to embedded prototype with only the once per week seminar class as a guidance mechanism. Starting "top-down" from the desktop towards the hardware encouraged software-centric students to safely start exploring hardware concepts. Several students became so engaged with their mobile platform project ideas (Fig. 2, portable ECG, balloon sensor system) that they spent significant extra time learning electronic circuits well beyond the course outline.
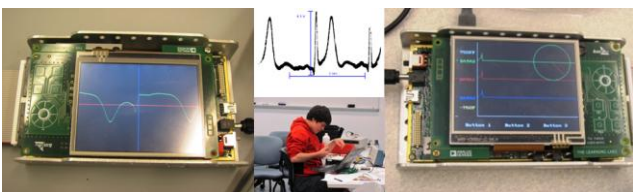

Figure 2. Olin Projects – Portable ECG, Balloon Sensor System

The freedom to work outside of fixed lecture/lab times, and the ability to run untethered after programming, the mobile platform allowed students to explore a broader range of technical complexity and realism for their projects. All teams were inspired to take on projects requiring significant new skill development beyond the scope of the formal seminar content.

B. NEU - Microprocessor-Based Design Course

The NEU Microprocessor-based Design (MBD) course is a highly structured format using the traditional lecture and lab model typically found at many universities. The class size a mix of 4th and 5th year ECE undergraduate students. All students would have had exposure to industrial environments from their co-op experiences with industry. The MBD course was based in past years on a commercial microprocessor development board, as introduced by Kaeli [18], and is taught "bottom-up" starting from low-level hardware concepts up through assembly language and C language development. For 2010, and in 2011, Schirner upgraded the course to use the Gen2 mobile system and we have gathered valuable experience from this course. The mobile system was used in the laboratory mode to observe first-hand the patterns of usage by students prior to allowing out of lab use. Two 100 minute lecture time slots were accompanied by 120 minutes of lab time per week. In five two-week lab exercises students explored the principles of embedded software development and hardware architecture. In addition, the lab contained an open-ended project of the students' choosing allowing them to combine concepts from various lecture concepts and lab exercises. It is the first time that the course permits an open project, and students have enthusiastically embraced the opportunity. Project topics were portable systems such as a hand held signal analyzer and a compressed audio wireless link (Figure 3). The course end survey results (Table 1, averages for 2010-2011) indicated positive student experiences with the platform-based labs.

TABLE I.   NEU MBD COURSE LAB SURVEY RESULTS

QUESTION (SCALE 1-VERY LOW TO 6-VERY HIGH)	SCORE	ST.DEV.
DIFFICULTY LEVEL	4.0	1.3
AMOUNT LEARNED	4.3	1.2
USEFULNESS	4.7	1.1
CONNECTION TO LECTURE	4.4	1.3

The platform-based labs were a precursor to student-defined open projects in the second part of the semester. A large portion of the course success can be attributed to using the open platform. Students reacted very positively and were intrigued by the computing power and versatility, which also triggered students' creativity. It is interesting to note that all groups have expanded on their own initiative beyond the concepts formally taught in the course syllabus: two groups used the LCD interface although graphics drivers were not covered in the class; the other two groups have expanded base system for wireless communication, and RFI interfacing,

respectively. Given the self-selected project motivation students naturally opted for self-learning to reach their goals. Students were ambitious with their project ideas, and highly motivated to follow them through. The lab projects also had a valuable integrative component, combining knowledge from different domains. Students have on their own incorporated material from other courses into their projects. One group explored basic radar technology, another integrated complex digital signal processing, yet another was interested in networking aspects – all concepts beyond the scope of this course. We saw that the freedom offered in the final project leads to a student-centered integration of the different subject matters. .

When surveyed, 80% of the students indicated that having a personal active learning platform would be very beneficial to their academic progress. They gave concrete examples of "developing at home", "some debugging ahead of time", and "playing at home". Only one student was indifferent and cited time limitations as a restriction.

Figure 3. NEU Projects – Signal Analyzer, Wireless Audio

VII. FUTURE DIRECTIONS

Phase 2 of the platform trials expands the set of courses in which students will have personal units for 24/7 use. The initial scope will include Computer Architecture, DSP, Introduction-to-ECE, and HW/SW CoDesign. We then plan to apply the mobile platform approach to a broader set of courses such as Digital Systems, Biomedical Electronics, Signals and Systems, and Communications. The set of courses represents very different subject domains, faculty approaches, and course objectives. We aim to explore several learning objectives:

- Expansion of time. Students will have platforms from their first year introductory courses through their final capstone projects. Students can spend more time on the task.
- Enable location independence. With 24/7 availability, practice opportunities can expand well beyond the lab.
- Integration over subject matter. With a heterogeneous system, we can integrate over subjects from introductory courses, to core subjects, and then to specialized electives.
- Increasing student motivation. Through the personal use model, we anticipate that students will develop greater autonomy and ownership for their learning.

In conclusion, we have developed an open mobile platform approach for integrating active learning into the EE/ECE/ICT curriculum, and the initial feedback from the first phase course trials is that the approach can work across institutional and age boundaries. The second phase of this experiment is in progress with an expansion to a broader range of subjects.

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