A Dialog on Mobile Studio

By Mohamed Chouikha and Ken Connor

Can you give us a little background on Mobile Studio? What is its history? What are its cost and capabilities?

The Mobile Studio is a small, inexpensive hardware platform for use in a home, classroom or remote environment. When coupled with the Mobile Studio Desktop software, the system duplicates a large amount of the hardware often used to teach electronics intensive courses in ECE and other STEM disciplines (e.g. scopes, function generators, spectrum analyzers, etc.). The goal is to enable hands-on exploration of STEM education principles, devices, and systems that have historically been restricted to expensive laboratory facilities.

The Mobile Studio was the brainchild of Don Millard, who presently serves as a Program Director in the Division of Undergraduate Education at NSF. In 1999, he was at RPI, where he was looking for a way to make Studio Pedagogy work more effectively and much more affordably. Studio instruction, developed at RPI primarily in the 1990s and used in essentially all of the core electrical and computer engineering courses (for which RPI's ECSE Dept. received the ECEDHA Innovative Program Award in 2001), was found to be a very good way to deliver engineering education, especially in ECE programs, and attracted a steady stream of visitors all of whom went away hoping they could implement something similar. However, with very few exceptions, none were successful because the costs were so high. In round numbers, the facilities necessary to provide lectures, paper and pencil problem solving, numerical simulation and traditional experiments all in the same room, cost about $10k per seat, which is just not practical.

Don's vision for a new, inexpensive studio for teaching electronics was based on replacing the very expensive standard set of instruments found on a typical lab bench (scope, power supplies, function generators, multi-meters, etc.). He hoped that someone was selling something he could use for this purpose, but nothing he found met his needs. His next step was to design and build a small board that could duplicate the functionality he needed. With the help of Analog Devices and Doug Mercer (an ADI fellow who graduated from RPI in '77), an amazing RPI student (Jason Coutermarsh, who now works for ADI), funding from NSF and Hewlett-Packard, and the help and support of a growing, but small number of true believers (including the authors of this piece), he went through several designs, with varying degrees of success, until what is called the RED2 board became generally available in 2008. Earlier designs (including RED and BLUE) showed that his idea works very well, but were, as a colleague at Rose-Hulman has said, not quite ready for prime time. The RED2 board had all the necessary functionality required and the robust design to survive regular usage by undergrads. Information on all three boards, along with the software necessary to run them, etc. can be found at mobilestudioproject.com. All three boards were designed by RPI personnel (Don and Jason, primarily, who also arranged for and supervised their manufacture). The cost of each was about the same as a textbook or about $150.

How difficult is it to adapt existing experiments to Mobile Studio? How much effort is required for a trial run? Are there any limitations in developing experiments vs. standard equipment? Are students able to use standard equipment after learning on Mobile Studio?

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Because the Mobile Studio platform contains most of the instruments necessary for standard electronics experiments, adapting existing labs generally only requires a different set of instructions because the wires have to go to different places. It is also the case that the instruments available through Mobile Studio do not have the bandwidth or dynamic range of more expensive, standard instruments, so some experiments must be modified to work at lower power or under 200kHz. This is generally not a big issue because most basic circuits and electronics are best taught in the audio range anyway. It is possible to modify the experiments in an existing course, over the term of a semester, without the need for special outside work. This has been done at several universities, including, most recently, UW-Madison. A short description of the innovations they are pursuing in engineering education are described in their annual report http://perspective.engr.wisc.edu/2012/08/active-engaging-education-anywhere-and-right-here/ which includes a short section on Mobile Studio.

An example of the efficacy, ease and immediate results of the Mobile Studio approach is a trial session done several years ago at Howard University. Using a make-shift studio space, a few fold-up tables/chairs and a wireless network, the set-up took only 30 minutes and by 8:00 am the session started. Twenty students (self-organized in teams of two) participated in this activity. After a 30 minute overview of the activity (incorporating the "Filters CAD" module) with a demonstration of a working circuit (using an electric guitar as the input signal), students were given 90 minutes to construct and test their designs. All of the teams created protoboard versions of the circuit and tested them with the instrumentation, while 6 of 10 successfully demonstrated a functional circuit. The participating faculty, students and administrators were so impressed and excited with this result that the following semester the Mobile Studio was formally introduced in the junior electronics course as part of EE curriculum at Howard.

The equipment necessary for the trial run at Howard, with the exception of the guitar, fits in a standard carry-on travel bag. This makes it possible to offer workshops and outreach activities almost anywhere, as long as the participants have laptops. We have given workshops, run K-12 programs, etc. in many different countries with minimal difficulties because everything is so small. There are now universities in Africa (e.g. in Cameroon and Ethiopia), RET programs serving teachers in Native American schools (e.g. through the CIAN ERC at Arizona), community colleges, etc. all using Mobile Studio because it is so simple to create the experience anywhere and anytime. Our colleague from Morgan State – Yacob Astatke – has been particularly active in improving engineering education in his home country of Ethiopia.

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One of us (KC) recently received the following question from Israel.

I came across info about the Mobile Studio h/w and s/w and went through the stuff in your site and some tutorials on YouTube. I like the idea of working with Mobile Studio which seems like an available inexpensive solution. However, I got the impression that from a student's point of view there is not much difference between the MS and using simulation such as Matlab (that students are currently using in a communication class). After all, students are not using a real scope, function generator, or a spectrum analyzer, but rather a s/w interface which may seem similar to a Matlab simulator. Dr. Avi Silbiger, Jerusalem College of Technology.

You have done a nice job of asking one of the questions we get fairly often, but in a well-defined context. Restating your question somewhat – if students see the same information through a software interface, how is the experience really different from a simulator? In fact, there are a few very minor aspects of using the Mobile Studio that differ little from a good simulation. For example, it is possible to use one of the Arbitrary Waveform Generators to reconstruct a square wave from its harmonics and play it back directly through connections on the board to display the results on the oscilloscope. One can listen to the signals using the audio output to obtain a sense of what harmonics mean. Clearly, this can be done using Matlab. Nothing is physically connected to the board … no physical components are used … etc. However, very, very little of what we do with Mobile Studio is anything like this.

Before I get into the real differences, I will address your statement that 'after all, students are not using a real scope, function generator or a spectrum analyzer…" As I explain to my students and everyone else who I talk to about Mobile Studio, what we have really is a collection of real instruments … just not ones in boxes with the usual knobs and displays. NI, especially, and Matlab, to a lesser extent, also struggle with the misconception that a small piece of hardware connected to a computer is less of an instrument than the big old scopes, etc. that we have used forever. I think all of us suffer somewhat because of the unfortunate name that NI gave to their control programs – Virtual Instruments or VI's. In some of the documentation I give to my students, I carefully draw boxes around each part of the board so that they see it as a very compact collection of boxes and not just a board with lots of connections. I also point out that modern instruments are really configured largely the same way except that they are self-contained rather than share a single computer. For example, in my radar lab, I have high frequency spectrum analyzers, network analyzers, oscilloscopes, etc., all of which I can operate remotely from my laptop because they all are Windows boxes. They are computers that look like instruments.

OK, so much for philosophy … What is the student experience like (addressing the rest of your sentence)? First, we do exactly the same experiments we did with standard instruments (mostly Agilent, with the cost of a single station greater than $10,000). We build all the basic op-amp configurations and measure the input and output voltages on the breadboards. Students get all the same experiences they have with real experiments, including dealing with noise, poor connections, power limitations, etc. All of the materials for my course are available at http://www.ecse.rpi.edu/courses/F12/ENGR-2300/ElecInst.html. Once the students master the use of Mobile Studio, teaching them to use a standard oscilloscope is very simple. In fact, colleagues at Rose-Hulman have found that students learn the concept of scope measurements much more quickly with Mobile Studio than with standard equipment.

It is not just that the students have a real hardware experience in the classroom, essentially identical to what we got in the past with standard scopes, etc., what is really powerful is that each student is given a full set of tools similar to those used by practicing engineers. I discuss this in a document I give them http://www.ecse.rpi.edu/courses/F12/ENGR-

2300/Differentiators%20and%20Integrators.pdf in which I address the tools required for an engineering design cycle which includes both simulations and experiments. Students get to work with the same kind of tools they will have on the job as they learn to be engineers. Even more important, they own these tools and can use them anytime and anywhere. Thus, the learning they do based on hardware experiments is not limited to a classroom they only see 2 or 3 hours per week, but can be continued at home and with friends. Note that instructors also have the freedom to try ideas out at home in little more space than it takes for one's computer. Check out the article I just wrote for the Chronicle of Higher Ed on this topic:
http://chronicle.com/article/With-a-Mobile-Circuit-Board/134688/
In the end, this approach is very attractive if one believes in the value of hands-on experiments, not just simulations.

There are other programs similar to ours that we are now collaborating with. Kathleen Meehan at Virginia Tech, for example, offers Lab-In-A-Box classes that never really meet in the traditional sense. Students do all of their labs at home and then come in to demonstrate their results. They use different hardware and, ironically (given your questions), used a Matlab interface for their measurements. Thus, it really can look like a simulation on first glance, but then you see the actual experiments with all real-world characteristics included and you see that the students are having a complete learning experience.

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I understand that Mobile Studio boards are no longer available but Digilent has a new product that can easily replace it. Are there any other options available if one is interested in pursuing this approach to engineering education?

We have indeed stopped manufacturing Mobile Studio hardware. However, there are still several hundred boards which can

be purchased by interested parties. A better choice, though, for long-term program development, is one of the similar commercial products. The new Analog Discovery board from Digilent (http://www.digilentinc.com/Products/Detail.cfm?Prod=ANALOG-DISCOVERY), developed in collaboration with Analog Devices, provides the same functionality as Mobile Studio with better specs and a lower price. This seems to be the curse of the industries our graduates work in – everything must simultaneously get better and cheaper. Analog has completely revamped their excellent university program around Digilent's board. There is an excellent video on the program at http://videos.analog.com/video/1875694804001/Analog-Devices-University-Program/. The Virginia Tech Lab-In-A-Box project is now using the Digilent board. The NI myDAQ (http://www.ni.com/mydaq/) is also an excellent choice for what we are now calling Mobile Learning Platforms. Bonnie Ferri's TESSEL Center at Georgia Tech has had great success in adding hands-on content to existing ECE courses using myDAQ. There are other products on the market, but these two provide the most extensive support infrastructure and are or are becoming widely used.

Mobile Studio, TESSEL and Lab-In-A-Box have all been supported by NSF through the CCLI (now TUES) program. A collaboration of the participants in these programs (The Center for Mobile Hands-On STEM) presently has support from TUES. The universities involved are RPI, Virginia Tech, Georgia Tech, Howard, Morgan State, and Rose-Hulman with assessment provided by the University at Albany. Several other universities and community colleges are actively applying the pedagogy being developed at the new center.