Work in Progress: Applications of Internet of Things (IoT) in Distance Lab Checkoff

Dr. Mohammad Habibi P.E., University of Wisconsin, Platteville

Biography I received my bachelor and Master degrees in Telecommunication engineering from Iran University of Science and Technology in 1993 and Isfahan University of Technology in 2000, respectively. I started my engineering career as an RF engineer at Telecommunication Company of Iran in 1994. My primary job duties were designing, maintaining, troubleshooting multiplexer systems and RF links between cities and villages. I loved my first career and held it for more than 8 years. I went back to school for Ph.D. in 2005 and earn my degree in 2010 from University of Wisconsin-Milwaukee. The focus of my doctoral work was differentiating material based on their dielectric properties. After completing one year of post-doctoral training, I joined Minnesota State University-Mankato, the department of Integrated Engineering as an assistant professor in 2011. I moved back to Wisconsin and joined the department of electrical engineering at the University of Wisconsin-Platteville in 2014. In addition to academia, I always have a passion for industrial work. I have been working as a consultant for engineering firms such as AEI engineering in Madison as Instrumentation and Control Engineer in my spare time. In addition to biomedical research, I have been interested in engineering education since 2011. I am an active member of ASEE, and have published a number of papers in the area of student learning, capstone design, etc.

Miss Emily Teresa Carbaugh, University of Wisconsin, Platteville

I am a junior electrical engineering student at the University of Wisconsin-Platteville.
Abstract: Many colleges and universities provide education for students who are unable to attend classes in person, called distance learning. Distance learning facilitates adult students who often have family and work commitments. For the last two decades, engineering schools have been offering distance courses over the Internet, which is a common method of facilitating distance courses. Since lab activities in engineering fields are a crucial part of learning, providing same laboratory experience that on-campus students receive for distance-learning students has remained a challenge. This challenge consists of both the lack of laboratory equipment and the limited availability of the instructor for assistance and checkoff.

Electrical lab equipment, such as a function generator, oscilloscope, and power supply, are expensive to purchase and maintain. Additionally, it is not possible to build many lab stations close to distance learners. The limited availability of instructors to verify students’ work has made it difficult for students to receive the help they need to complete projects. Multiple methods, such as lab simulators or a remote laboratory, have been proposed and used to address these challenges based on the idea that simulators can replace the physical experiments. There are multiple software programs that enable students to design electronic circuits. These programs contain virtual instruments such as oscilloscopes, function generators, and logic analyzers that can be used to simulate and observe the voltages and currents at various points of a circuit. However, no simulator can completely replace the actual hands-on laboratory experience.

Fortunately, inexpensive lab equipment such as Analog Discovery is available for distance students to build and test their circuits. To address the checkoff issue, distance students commonly are asked to provide a webcam and arrange a time with their instructors to verify the experiment results. In this paper, we propose a method based on Internet of Things (IoT) to enable distance students to store their test results in the cloud. Therefore, instructors can check them off based on their data, which can be available anywhere at any time.
Introduction

Distance education, distance learning or online education refer to the education provided for students who are unable to be physically present on campus. An extensive review on literature and current information related to distance learning has been reported [1]. Many schools are now offering engineering programs as a part of their distance education across the globe. Distance education delivery methods began with broadcasting the courses on national TV and with sending video tapes and written study material to the students. These methods of delivering distance education have significantly changed and improved within the last decade as a result of the speed and the accessibility of the Internet. Students are now able to read, watch and perform their assignment via web pages. Additionally, they may discuss their assignments, lecture notes, and other course related material with other students or with their instructor by joining an online discussion forum or by posting their questions on web sites.

Although distance learning has been effective for non-engineering courses, distance engineering students face multiple challenges. One of the problems in teaching engineering topics via distance learning is the lack of laboratories where the students can perform real experiments. For example, an electrical engineering student must perform various practical experiments using transistors, operational amplifiers, and other components to verify theories and to learn troubleshooting.

The first solution applied to address the lack of laboratories was the use of simulators [2,3,4]. Computer simulation is used in industries wherever the practice of conducting experiments on a real system is either impractical or impossible, often because of cost or time. Not only is lab equipment costly to purchase and to maintain, they require physical space. On the other hand, simulators are relatively inexpensive and can be installed on any computer, a significant advantage for distance education. Electrical engineering students are encouraged to use computer simulation even where lab equipment is available. Simulators enable students to predict experiment results and are especially useful to ensure a circuit design meets given specifications. Using online simulators, students from all around the world can perform experiments together as a way to enhance the participants’ intercultural competence [5].

A remote laboratory method, such as Virtual Instrument Systems in Reality (VISIR), consists of a combination of physical and virtual lab equipment [6]. VISIR permits wiring and measuring electronic circuits remotely on a virtual workbench that replicates physical circuit breadboards. In this technique, a relay switching matrix controlled by LabVIEW software is used as a wiring mechanism. A similar method reported the use of robots, which are remotely controlled by students, to assemble a circuit [3]. Other methods such as remote labs based on Data Acquisition Cards (DAQs), NetLab, and RemotElectLab, are investigated [6]. While simulators and remote laboratories can be very useful tools in teaching, they are merely theoretical and only provide a digital presentation of data, which cannot replace the hands-on experiments. In many cases where these methods are used, simulations work easily, but students have a hard time performing the physical experiment. Lack of experience in manual troubleshooting, debugging and equipment-setup are the weaknesses of these methods.
The third approach is to require distance students to make one or two trips to the main campus for laboratory work. This method is feasible if both students and instructors have time to meet on specific days to execute labs. Most distance students commonly have family and full-time job commitments, so choosing a day that works for everyone in the class might be a challenge. However, for some majors that require an expensive lab facility, this might be only a practical option. It has been reported that the performance of students on and off campus using this method is comparable [7].

Incorporated within the third solution, distance students receive or purchase a kit that enables them to carry out small experiments at home in order to fulfill requirements. This solution works best for only some engineering courses, such as circuit modeling, electronics, logics, instrumentation, dynamic systems, etc. A proposal for changes to the package and to other curriculum resources that would enhance the use of the kit by distance students is also presented [8]. The question remaining under discussion is how they can check off their experiment results. Students can set up a webcam and perform the experiment under their instructor’s supervision, but this is a greatly time-consuming approach for both learners and instructors, who already have busy schedules.

In this paper, we suggest a new approach based on Internet of Things (IoT) to facilitate students’ lab checkoffs. The IoT is predicted to have a profound impact on our daily lives and become an essential part of areas such as healthcare, water resource management, power distribution, transportation, industrial control, retail, utilities, management, business, etc. The IoT is defined as a network of Internet-connected objects, which exchange data, keep track of other objects by sensing their surroundings, and report it to other machines as well as to humans. Ideally, these objects are smart and can analyze, sense, and communicate with each other. They also are able to communicate with humans and enable us to monitor and control them anytime, anywhere and benefit from their smart services. It has been reported that there will be over 26 billion devices connected to the IoT by 2020.

As a new solution to the problems that occur with distance learning, we propose an IoT-based lab checkoff, which enables distance engineering students to perform experiments in their own places of study using real laboratory components and equipment. In fact, students are able to use this to perform real laboratory experiments and upload their results from anywhere at any time to a webserver. Using this method, instructors are able to monitor experiment results remotely using a mobile device such as IPad, smart phone, tablet, etc.

**Distance learning at the XXXX University**

As of fall of 2008, the department of Electrical Engineering at University of XXXXXXX, located in southwestern XXX, has been offering their electrical engineering (EE) program to distance students located throughout the state. This distance program is a result of collaboration between multiple two-year state colleges and the author’s home university. This distance-learning program facilitates student learning so they can complete the entire four-year engineering degree locally without having to travel to the main campus. Distance students usually are graduates from two-year local colleges. This allows them to complete some of their general education and
basic science courses before enrolling in the distance electrical engineering program. Some students may begin enrolling in the distance program alongside other prerequisite from their local colleges. The electrical engineering courses are offered via streaming video. While the instructors are delivering their lectures on the main campus, distance students are able to join the class live by a web-application (Blackboard) or watch the lecture later at their convenience. Since most of distance students have family and job commitments, they typically watch the lectures at night or during their break times at work. Deliverables and course expectations are the same for both local and distance students. The instructors usually offer evening online-office hours to answer distance students’ questions.

All but one of the electrical engineering courses (Electric and Magnetic Fields) have an integrated laboratory component. Like any other engineering program, the laboratory portion is highlighted and faculty expect all students to be able to verify theoretical concepts learned in lectures using lab equipment. While lower level classes accompany cookbook style labs, most senior-level courses are heavily integrated with design-based laboratory practice.

In order to make the lab delivery more effective, it has been decided to bring the labs to distance students [9]. As a result of an agreement between the main campus and the two-year campuses, a small local laboratory (only one station) is hosted by two-year colleges during the semester. A lab assistant from the main campus arranges lab times with students, brings and sets up lab equipment, and serves as a resource during the completion of the laboratories at these regional sites. In some cases, students are provided Analog Discovery units so they can carry out experiment at home. An Analog Discovery unit turns a personal computer into an electrical engineering workstation. The device provides a two-channel oscilloscope, a two-channel waveform generator, ±5 VDC adjustable power supplies, a 16-channel logic analyzer, a 16-channel digital pattern generator, a spectrum analyzer, a network analyzer, and a voltmeter. Students are then able to build and test analog and digital circuits at home using these features. One issue with performing experiments at home has been the lab checkoff. For any experiment, the instructor must verify the students’ results and make sure that these results are correct and genuine. Currently, students need to perform the experiment while the instructor was watching them via a webcam. Finding a time that works for both the student and instructor has been a problem because distance students usually have limited availability during weekdays.

**IoT to facilitate remote lab check off**

The use of IoT technologies in remote-controlled laboratories has been reported. For instance, an IoT-based technology unit has been presented for facilitating learning chemical reactions [10]. A simple IoT setup consists of sensors, actuators, internet-connectivity, a microcontroller and a webserver. Sensors can sense physical properties such as temperature, humidity, pressure, etc., and as a result, a voltage signal is generated. After proper signal conditioning, the microcontroller transmits associated digital values to the webserver via the Internet. This method facilitates remote monitoring of a process in real time. This method also can be used to monitor students’ experiments if their data is measured and transmitted to a webserver. Subsequently, instructors can monitor experiments remotely anywhere, anytime. Figure 1 shows the basic block diagram of the system. The following is an example:
Example: Course, project and students

The Measurement and Instrumentation course is offered in many engineering and technology schools to introduce undergraduate engineering students to the measurement principles and instruments used for measuring physical quantities. In recent years, advanced topics such as smart sensors, intelligent instruments, and digital components (e.g. storage, displays, interfaces, etc.) have been added to the content of the course. Applications of this course include, but are not limited to, building automation, industrial control systems, and safety controls. At the University of XXX, a new IoT module has been developed and added to the measurement and instrumentation course. The module consists of five hours of lectures, which cover the theory of IoT and a design lab project. The design project requires students to implement the theory into a practical application. As the final project for this course, students are required to design and prototype an instrumentation which contains multiple sensors and actuators combined with IoT concepts.

Two electrical engineering distance students, located approximately 100 miles apart, participated in the final project of the course during the spring 2017 semester. Their project was a home monitoring system that included a carbon monoxide sensor and a smoke detector. The carbon monoxide sensor monitors the environment for unsafe levels of carbon monoxide in one location and the smoke detector monitors the environment for smoke caused by a fire at another. Each sensor is calibrated to respond to a specific level of smoke or carbon monoxide. The carbon monoxide sensor produces a digital output while the smoke sensor produces an analog output. Unsafe conditions will result in an alarm being triggered and a text message being sent to the homeowner’s phone. Figure 2 displays the circuit schematics of the project. The alarm includes both audible and visible indicators. The light color of the visible indicator and the sound pattern of the audible indicator are unique for each sensor. The sensors in both houses of the distance students were monitored and controlled through an internet-based Graphical User Interface (GUI). Figure 3 is a snapshot of the GUI. Since the monitoring capabilities were available at anywhere, anytime, the course instructor had no issue checking the project off. The instructor
received text messages when the students were testing the project and he was able to monitor both houses remotely via the GUI. Although this is a specific example, it provoked the notion of using this method to checkoff distance students’ experiments that are executed at home.

**Figure 2. Circuits schematics**

**Figure 3. GUI showing the sensor outputs at two locations**

**IoT Logistics**

An IoT setup for voltage measurement is shown in Figure 4. The setup includes a set of hardware and software. In the following, the set of hardware and software will be described.

Assembly of the hardware: most IoT devices primarily use pre-assembled boards and sensors connected to them. These devices require programming skills to read the data from the sensors connected to the IoT device and send them to the server. A microcontroller, which has WiFi or Local Area Network (LAN) connectivity, is required to build the setup. If only one measurement needs to be taken, ESP8266 is a good option. ESP8266 is inexpensive and has WiFi capability, but it offers only one analog input, which means the system can accept only one input below three volts. If multiple probes for measuring multiple outputs are required, an Arduino or any
microcontroller with multiple analog inputs will complete the task. Implementing a voltage follower would isolate the microcontroller and the measurement point. A voltage follower can be designed to adjust the voltage level making it suitable for analog inputs.

Webs server: in addition to hardware, a server must be deployed to receive and store data from the device. This requires the use of server-side languages, like PHP, ASP.NET or Node.js, and database queries based on MySQL or some other SQL derivative. Another task is to display the data from the users via a Graphical User Interface (GUI). The GUI in the form of a web page or an app must be developed to disclose the collected data to the user. Fortunately, multiple platforms have been developed to minimize programming for users. For instance, Adafruit.IO is a free, easy-to-use service that allows simple data collections with little programming required. For the project described above, students used Adafruit.IO. Other IoT Cloud platforms that can be useful to create IoT projects include, but are not limited to, ThinkSpeaks, Eclipse Mosquitto, Temboo, etc.

![Figure 4. Basic IoT setup used for measurement. A non-inverting amplifier provides an infinite input impedance for the probe and R1. R2 adjusts the level of signal feed to the microcontroller.](image)

**Future work**

This paper presents a work-in-process idea to facilitate remote laboratory checkoff using Internet of Things. We understand that this method may not be usable for all engineering disciplines, but we leave this to instructors to investigate its applications in their disciplines. The idea is applicable to the lab work in which students are able to perform remotely on their own. Students perform measurements and their results are available in real-time to instructors via text messages, emails, phone apps or web-based graphical user interface. Faculty are able to see these results and provide immediate feedback to the students. This method works best for some electrical engineering courses such as Circuit Modelling, Signals & Systems, Electronics, Digital Circuits, Instrumentations, etc. The method can also be used for mechanical engineering students to report their real-time experiment results. For example, the development of a take-home package, consisting of software and hardware kits for mechanical engineering students, has been
reported [11]. This package enables students to perform laboratory experiments and measurements at home to illustrate system dynamics concepts. It is helpful if instructors are able to see the results concurrently.

As an example of a Circuit Modelling laboratory, the following circuit (Figure 5) is given and the students are required to set up the circuit and report V1 and Vo. Remote students should be able to set up the circuit at home and use the IoT device (schematic shown in Figure 4) to report the requested voltages to the cloud-based database. Additionally, smart analysis can be implemented into the system such that students automatically receive confirmation of their results or even tips for troubleshooting. We hope to receive feedback from educators who will implement this technique for their distance lab checkoff. Since this method has been successfully tested for the Instrumentation and Measurements course, our next step of this work is applying this method for a variety of electrical engineering courses at the University of XXXX.

![Figure 5. Circuit Example (From Alexander et al. p185)](image_url)

References


