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THE TECHNOLOGY INTERFACE INTERNATIONAL JOURNAL EDITORS

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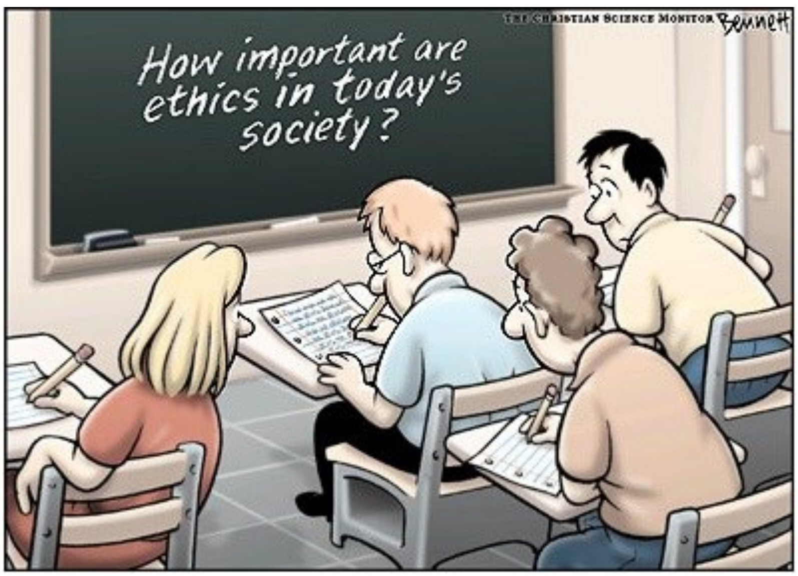
ETHICS IN ENGINEERING EDUCATION

Philip Weinsier, TIIJ Editor-in-Chief

If you read the title of this Editor's Note and are now reading my actual "note," then you may well learn something. But I'm guessing that most who read the title already believe (rightly or wrongly) that they do the right thing, at least when it comes to publishing, and can forego this part in favor of the more interesting articles contained in this issue. But doing the right thing (a moral precept) is not the same thing as following the rules of the game (ethical code). Over my 40-year teaching career, I've published my share of articles and books. But since becoming the Editor-in-Chief of this journal (TIIJ) back in 2010 and the senior editor for our other two IAJC journals (2008), I've learned a lot about ethics.



If I'm being honest, prior to 2010, I would surely have said that I always do the right thing—that my moral compass was pointed in the right direction—and that I always followed the rules. But if I'd been pressed, I would have to have admitted that I didn't always know what the rules were; no one ever explained them to me, as I dealt with many different publishers and felt that I needed to focus on THEIR rules rather than following more overarching rules of PUBLISHING. So I'd like to focus this Editor's Note on what I feel are the ethics, the rules, of publishing, and not simply the rules of IAJC.

As I noted above, a moral precept is an idea—or even one's opinion—that one holds as the right thing to do, whether that involves one's friends, family, strangers, the environment, etc. An ethical code, on the other hand, is made up of actions or behaviors or, basically, a set of rules that defines these actions and behaviors. One's ethical code does not define one's set of beliefs. Rather, it is comprised of a set of rules that ensures that a person acts in such a manner as to bring credit, honor, and trust to one's profession.

All humans are animals, but not all animals are human. Similarly, what's ethical isn't always what's moral, and vice versa. For example, omertà is a Southern Italian code of silence, honor, and conduct among members of the Mafia. Members place importance on silence in the face of questioning by authorities and actively choose not to cooperate in criminal investigations and willfully ignore and avoid the illegal activities of others—for example, not contacting the authorities even if you are witness to or are in any way involved in a crime. So, by adhering to the rules of your organization, you are exhibiting ethically correct behavior. From a moral standpoint, however, many would consider this as morally incorrect behavior.

I would like to now say, let's cut to the chase, but I guess it's a bit late for that. If you've published with us (IAJC) previously, you have already been required to answer a number of ethical questions: 1) The work that you're submitting to us for possible publication has not been published previously; 2) The manuscript/paper is not currently under review by another journal; and 3) You agree not to submit the same manuscript/paper to another journal—to be reviewed for publication—before having received a final decision on acceptance from the IAJC journal (or until you have officially withdrawn the work from the IAJC review process). Furthermore, during our review process, you likely have also been asked to: 4) Ensure appropriate acknowledgements in your manuscript/paper; 5) Be careful when writing about work done by others, as this can lead to plagiarism; 6) Be particularly careful when referencing work that you yourself have published previously, as this, too, can be considered self-plagiarism; 7) Provide informed consent from any people whose likenesses you have used; and 8) Sign a copyright agreement form. There are certainly many more ethical rules that may need to be followed when dealing with other publishing outlets. I'm only asking here that you be aware of basic ethical standards; when in doubt, be sure to ask your publisher.

In the article in this issue by Marilyn Dyrud ("Ethics Cases and Technical Courses: Some Suggestions"; p.23), she makes an argument for embedding ethics cases in engineering and engineering technology education courses in order to meet ABET criteria.

Editorial Review Board Members

Developing an Educational Setup based on an Electromagnetic Linear Actuator

Maged Mikhail, Purdue University Northwest

Abstract

The author chose this particular project in order to demonstrate how to build, design, and program an electromagnetic linear motor portable trainer that could be used in several hands-on lab activities for the engineering and technology programs. While these electromagnetic drives have a higher initial cost, the overall cost is greatly reduced, due to a longer lifespan and easy maintenance resulting in less company downtime and costs associated with replacement parts and labor. Electromagnetic linear drives can be integrated with a variety of controllers, such as programmable logic controllers (PLCs), and triggered with 24V inputs such as switches, sensor I/O, or directly through the PLC. For the scope of the project, the author created a state-of-the-art portable trainer system to be used in the lab to enhance students' hands-on skills using new linear actuator technology. The system consisted of an electromagnetic linear actuator from LinMot USA along with hardware and software from Rockwell Automation. The Micrologix 1100 PLC actuated the LinMot motor via digital I/O on a PLC system to generate the proof of concept; however, these systems can be integrated with large complex systems spanning multiple industries.

Introduction

The LinMot motor drives have an easily programmable system that can be integrated into today's ever-increasingly automated industries, even when high speeds and accuracy are requirements ((NTI AG, 2021a). Electromagnetic actuators will be used to replace the traditional pneumatic cylinders in many applications—automotive, packaging, medical, pharmaceutical, etc. "The reasons include poor efficiency, high costs for commissioning, reconfiguration, service, and maintenance, and the limited control capabilities of pneumatic systems" (NTI AG, 2021b). For instance, along a production line, this could be used to reject a bad part by pushing it off a conveying system into a reject bin. With the motor's customizable speed, range of motion, and wide range of I/O functions, it can easily be integrated into a system like this. Compared to pneumatic pistons, the motor can also send an error signal to the PLC in the event the motor faults out; the signal could also be used to stop the current process, such as conveyor movement, to easily prevent immediate and future damage to the system from occurring.

This current project initially started as a post-undergraduate project for Purdue University Northwest to create PLC trainers that integrated LinMot linear actuator systems to simulate programming and troubleshooting in real-world applications, where PLCs and LinMot drives are integrated (NTI AG, 2021b; LinMot, 2015). Figure 1 shows how the new integrated system was developed with the intention of creating a compact housing for all of the equipment so that it could be stored and used inside a hard-shell case. The housing for this system was a Pelican IM 2620 Storm Travel case. The dimensions for the case were 20.0"x14.0"x10.0" (interior) and 21.2"x16.0"x10.6" (exterior); the total weight of this portable trainer after including all of the components was 45 lbs.

Figure 1. Designed housing for the system.

The process started by taking measurements of all the equipment needed and drawing CAD files of each component to get the size constraints of the housing (the Pelican iM2620 Storm Travel case). Next, multiple cases were found that would best suit the constraints and independent designs and made for the housing to fit inside the selected cases. One design and case were chosen after comparing all options. The housings were then constructed and equipment installed and wired. The last step was to program the PLC logic and the motor drive to work in synchronization with each other.

Design

The purpose of system design was to be compact but also so that the case could be easily removed for maintenance and modifications. To achieve this, the housing was designed using aluminum plating for its strength-to-weight ratio with wood being used as feet for the housing so that it would not scratch any surfaces when being worked on out of the case (see Figures 2 and 3).

Figure 2. Cutting aluminum plating and wooden base.

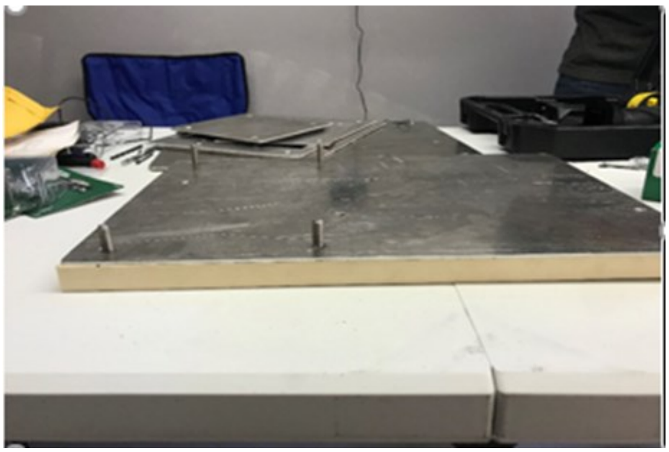


Figure 3. Housing for the system.

The aluminum plates were obtained from the university's supply of plating and were all cut using a plasma cutter to cut the shape, bolt holes, and equipment slots. The wooden feet had counter-bored holes so that the bolts would be above the bottom surface of the wood. Figure 4 shows the generic 90-degree brackets that were used to secure the plates to each other via 5/16 bolts.

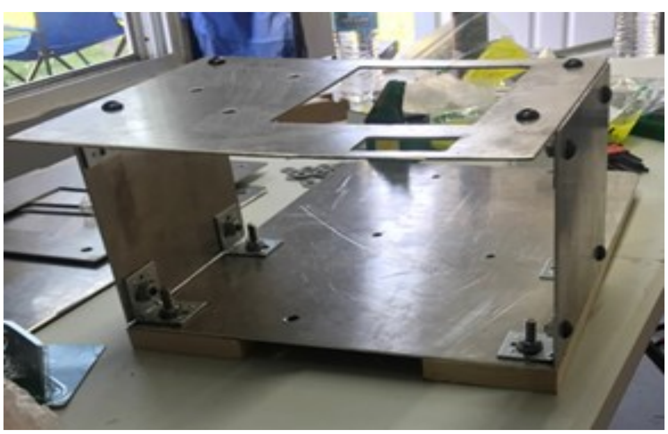


Figure 4. Setting up the enclosure.

Figure 5 shows how a DIN rail was installed on the bottom plate to secure some of the electronics and the PLC to the housing. The parts secured to the DIN rail were a 72VDC LinMot power supply, a 24VDC power supply, a MicroLogix 1100 PLC, and terminal blocks.

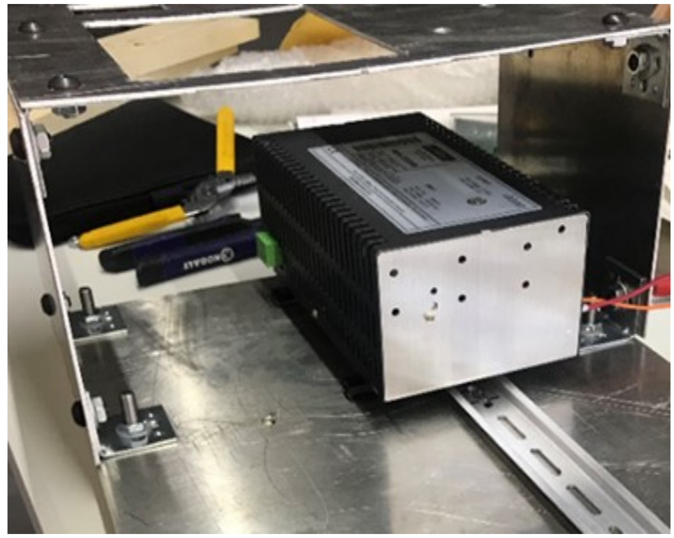


Figure 5. Installing DIN rail and LinMot power supply.

The LinMot motor drive was secured directly to the housing using 10/32 machine bolts with washers for added support. Figure 6 shows how the top plate was reserved for securing the motor flange, PanelView Plus 600, and the 120VAC fuse switch, for all installed hardware excluding the 120VAC fuse switches. All wires and cables were secured, managed, and isolated properly to avoid any potential electric hazard or shocks during moving or use.

Figure 6. Installing all system components.

After all of the hardware was installed, the next phase was to create a PLC program, a PanelView program, and configure the motor drive to actuate when receiving a signal from the PLC. The PLC program was a simple one, mostly consisting of a bit being actuated by the human machine interface (HMI), with the exception of a latch designed to stop a trigger function from being actuated while the motor was running in a continuous loop; this was incorporated because it was discovered that, if the motor was trigged for a single use while running in a continuous loop, the motor would fault out and need to be reset. Figure 7 shows the PLC program using RSLogix 500.

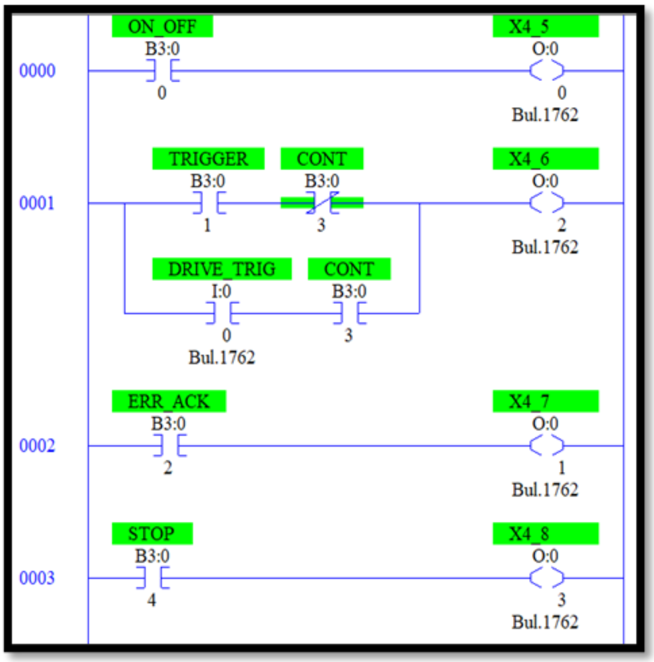


Figure 7. The PLC program using RSLogix 500.

The rest of the program consisted of the following functions: power on, home, error acknowledge, freeze, and go-to-position. Figure 8 shows that the HMI had accompanying digital buttons to trigger all the functions (LinMot, 2015; LinMot, 2016).

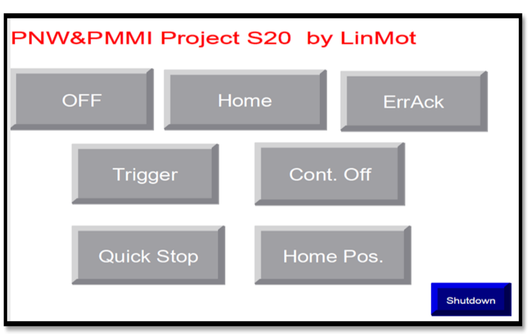


Figure 8. HMI design for system interface.

The motor drive was configured to receive an output signal from the PLC to execute the specified command, known as a control word, and in turn send a signal to the PLC to acknowledge that the command had been completed, known as a status word. To configure the motor drive, the X4 I/O definitions needed to be changed to the desired function as well as wired correctly to the PLC's I/O. One common ground wire was used for all components and to protect the motor drive. For the motor to execute a linear motion, the distance-over-time curve needed to be programmed in the software. Figure 9 shows that the curve consisted of a rise and a fall combined into a single curve; for this example, a curve of a rise of linearly extending 50 mm over 750 ms and fall of linearly retracting 50 mm over 500 ms was created to demonstrate tht the motor could perform asymetric actions.

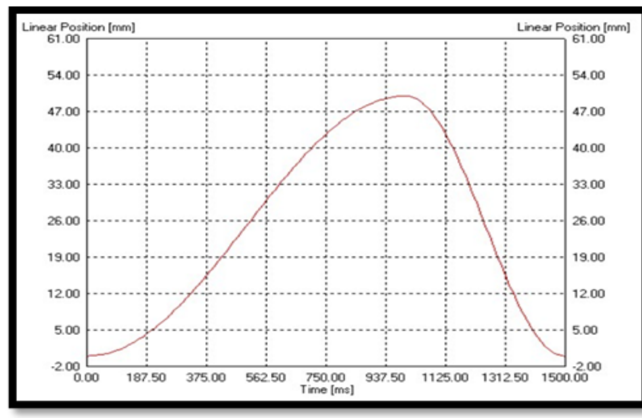


Figure 9. Curve operation for the LinMot actuator.

Testing/Troubleshooting

Once the build was complete and the programs finalized, the motor was ready to be tested. Once powered on, a power -on-command needed to be sent to the motor. Once powered, the motor would need to be put in its home position. Figure 10 shows that pressing the home button on the HMI would accomplished this function.

Figure 10. The system homing position.

Originally, the button had to be held closed until the homing function was completed. However, a latch function was added in the PLC program to allow the home function to complete itself until it received a signal from the motor drive. Figure 11 shows that, once homed, the motor was ready to be used; there were two functions integrated into the PLC program: trigger, and continuous.

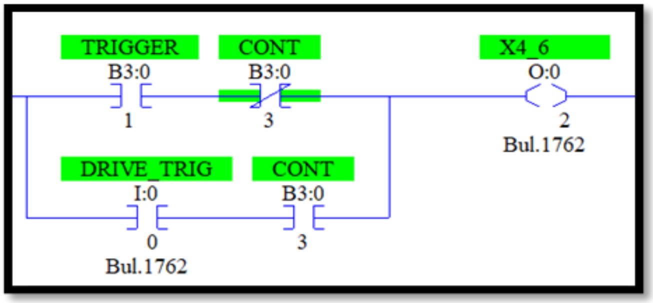


Figure 11. PLC program trigger and continuous.

The trigger function actuated the preprogrammed curve a single time, while the continuous mode would continually actuate the curve until the function was turned off. If the trigger function was actuated while operating in continuous mode, the motor shaft would stutter and the drive would fault, causing the motor to have its errors acknowledged and re-homed before the next operation. To avoid this, a latch function was incorporated into the PLC program that prevented the trigger function from being actuated while the motor was in its continuous operation mode.

Conclusions

The goal of this project was to design and build a portable trainer system that could demonstrate the capabilities of the LinMot linear motor system to be integrated into a PLC system. This system could be used in the future as a showcase of how it could be applicable in multiple hands-on applications in a mechatronics program. The system as created was contained inside a hard-shell case for ease of transport, while maintaining easy access to the PLC and motor drive I/O, in the event the configuration needed to be changed. The motor itself was easy to set up and integrate with the Allen Bradley MicroLogix 1100 PLC, with the motor drive being set up to respond to the PLC through the LinMot software. The motor was set up to turn on, home out, acknowledge errors, trigger, and continuously actuate in response to the commands received from the PLC. The software was found to be easy to use after watching a few of LinMot's setup guide videos and contained various research functions, such as the built-in oscilloscope that allows the user to monitor various parameters of the motor such as actual position, demand position, and electrical current. With versatility build into the motor, it could easily be adapted for industries currently using pneumatic pistons in production lines, package sorting, etc., while maintaining high speeds (200 inches per second).

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Biography

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An Affordable Home Alarm System Using Arduino Microcontrollers

James Holekamp, Martin Company; Clayton Vesely, Capitol Aggregates, Inc; Jeremy England, Weatherford, Inc;
Iftekhar I Basith, Sam Houston State University

Abstract

In this paper, the authors present a home alarm system designed and implemented using transducers and microcontrollers with wireless capabilities. The system consisted of a smoke sensor, motion sensor, and magnetic coupling switch sensor that individually reported to a server. Each microcontroller communicated with the central control hub through the 802.11 wireless standard using Message Queuing Telemetry Transport (MQTT) protocol. The central control hub was designed to display a mobile-friendly graphical interface over the network and was configured to send push notifications over SMS and email.

Introduction

The purpose of this paper is to provide a technical overview of the design and development of an affordable home alarm system. The home alarm system was designed to detect various gases, motion, and forced entry via a magnetic switch. The circuit for each sensor was configured with a microcontroller that reported to a central control hub that had a networked graphical interface and sent push notifications to email and/or SMS. The components of the alarm system included ESP8266 microcontrollers, ESP8266 serial interface transfer board adapters, a Sukragraha smoke detector board module, a MQ-2, Mausan MC-38 wired door sensor magnetic switch, a PIR motion sensor, 3.3V voltage regulators, and double-sided prototype PCB universal printed circuit boards.

ESP8266 Microcontroller

The ESP8266 microcontroller was chosen when deciding what hardware to use for the project. The ESP8266 is a low-cost, Wi-Fi capable microcontroller developed by ESPRESSIF Systems. It is equipped with a 2.4GHz radio capable of delivering +19dBm average power for 802.11b transmission and +16dBm for 802.11n transmission (ESPRESSIF). For context, this provided a wireless connectivity range that was comparable to the Wi-Fi built into a modern cell phone. The absolute range of the wireless connectivity depends on the output power and antenna sensitivity of a network's wireless access point. The chip can operate either independently as a microcontroller or as a Wi-Fi adapter for another device. The chip has two GPIO pins for analog or digital inputs and outputs and operates on 3.3 volts. According to the official datasheet, the ESP8266 contains the following hardware: a chip that uses a 32-bit RISC-based CPU running at 80 MHz; a CPU that features 64 kB of instruction RAM and 96 kB of data RAM; the ESP8266 also has 512 kB of built-in flash memory. A schematic for the CPU used in the ESP8266 can be found on the company's website (ESPRESSIF).

Software and Network Infrastructure

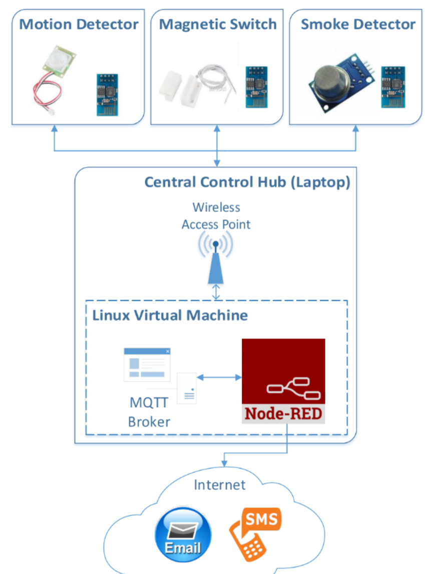
Among the top priorities of the project was to have a system that was presentable in the classroom. The vision was to provide a mobile-friendly web interface that would display the status of each sensor and provide warnings over text and email. Coming up with a solution that could do so while in the classroom required careful planning and extensive testing. The first major networking objective was to determine where and how the ESP8266s would communicate. The communication protocols that were originally considered included UDP, Modbus, and MQTT protocols. After conducting further research and experimenting with the considered protocols, it was concluded that the MQTT protocol was best suited for the project. MQTT is a machine-to-machine connectivity protocol that was designed as an extremely lightweight publish/subscribe messaging transport (MQTT, 2017). The protocol utilizes an intermediary message broker to exchange messages between devices. Additionally, the protocol was standardized by the International Organization for Standardization [Information technology – Message Queuing Telemetry Transport (MQTT, 2017)].

MQTT was chosen for the project for two main reasons. The first reason was that the simplicity of the protocol allowed for widespread support on low-power Internet-of-Things devices, such as the ESP8266. The simplicity of the protocol also enabled implementation with fewer lines of code when compared to other protocols. The second reason that MQTT was chosen was because the protocol runs over TCP/IP. Implementing a communications protocol that utilizes the TCP transport layer was a critical component of the project, because TCP provides error checking and correcting, congestion control, and a sophisticated acknowledgement system that ensures the integrity of all transmitted data from source to destination. To present in class, the web server, MQTT broker, and wireless access point all had to be hosted on the same local area network, due to blocked ports on the university's internet connection. To provide an isolated wireless access point, a virtual wireless router feature in the Windows operating system was used. On the same computer, a web server, MQTT broker, and interfacing software was installed on a Linux virtual machine. The web server and interfacing software was created together through a flow-based programming tool developed by IBM called Node-Red (Node-RED, 2017). The web interface was created with an extension of Node-Red called Dashboard. Since the virtual network adapter for the Linux virtual machine was configured to communicate through network address translation (NAT), the ports that were used by Node-Red and the MQTT broker had to be forwarded to the host machine. This was necessary for the virtual machine to communicate with the rest of the local area network. The MQTT broker was forwarded to port 81 on the host machine. Node-Red was forwarded to port 80 on the host machine, because it was the default http port. This eliminated the need to specify which port when entering the web server's IP address in a web browser when pulling up the user interface. Figure 1(a) shows a diagram of the project's network infrastructure.

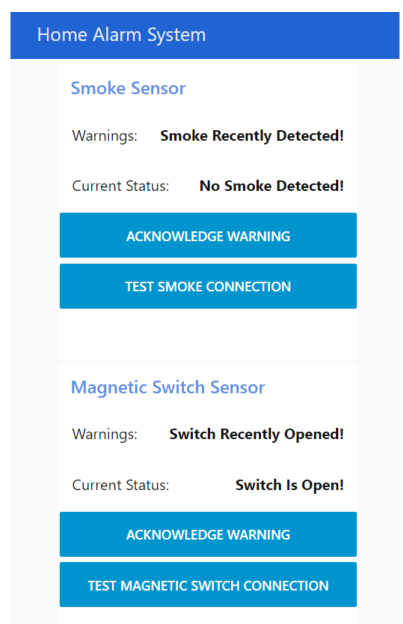
To enable text message notifications, a service had to be used that operated on a port that was not blocked by the university. Fortunately, a service called If This Then That (IFTTT) offered a solution for text notifications that operated on port 443, the default https port. Through the IFTTT service, an event-triggered web-hook was configured to activate a text notification. The web-hook was simply a web URL with a unique string that was triggered when an HTTPS POST request was sent. Node-Red was then configured to send the HTTPS POST request whenever a sensor was enabled. Email notifications were also configured for the project using simple mail transfer protocol (SMTP). Since the university network did not block port 465, the default port used for SMTP, email push notifications were configured directly in Node-Red. Figure 1(b) shows the interface for the mobile web app made with the Node-Red Dashboard extension.

Programming the ESP8266

The code for the ESP8266 was made as generic as possible in order to be able to work with a range of sensors and without having to change much except for a few variables. Constants that required the user's attention were placed at the top of the file and included topic, ssid, password, and mqtt_server. In the example code, the ssid, password, and mqtt_server were configured to "microcontroller," "12345678," and "192.168.137.1," respectfully. The only difference in code between the three sensors was the topic, the threshold of when to send the data, and whether a digital or analog read was required. The trigger threshold value of each sensor was placed into a variable called "value" and, in the main loop of the program, pin 2 of the ESP was read into this value variable and tested against the configured threshold. If the value was a digital value, only HIGH or LOW needed to be checked. If the value was analog, then a threshold of when to send the sensor's data was decided through careful testing. Rather than sending the sensor's data through the ESP every few seconds, the firmware was designed to send a message only upon a change in state. To manage sending notifications upon a state change, two variables were created called "isOn," and "wasOn"; these two Boolean variables kept track of the sensor's current state and prior state and were initialized to false when the code first started. If the sensor went above the desired threshold, the isOn variable became true and a nested if statement checked to see if the isOn variable was different from the wasOn variable. If the isOn and wasOn variables were different then the wasOn variable was also set to true and the code published the data to the "topic" with whatever message was decided by the user.



(a) Networking diagram for home alarm system.



(b) Graphical user interface for home alarm system.

Figure 1. Network infrastructure.

In simple terms, the sensor firmware would only transmit data to the control hub when the alarm state went from passive to active or active to passive. When the sensor's alarm state went from passive to active, the control hub was notified in such a way that it triggered an email and an SMS notification. When the sensor's alarm state went from active to passive, the sensor would still notify the control hub, but email and SMS notifications would not be sent. Figure 2 illustrates the logical flow for the sensor firmware.

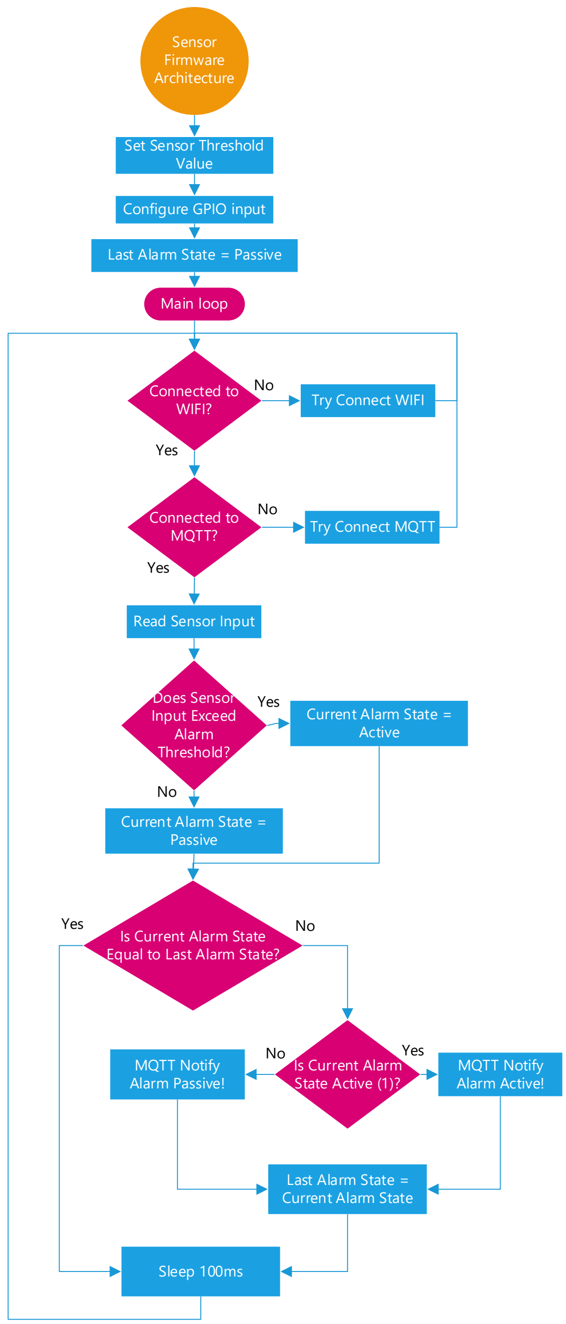


Figure 2. Flowchart for the sensor firmware.

Smoke Sensor

The SUKRAGRAHA smoke detector board module MQ-2 for Arduino was used for detecting smoke, LPG, i-butane, propane, methane, alcohol, hydrogen, and smoke (Smoke Detector Board Module MQ-2). This module was 32 mm x 20 mm x 22 mm and had four pins—V_{cc}, D_0, A_0, and Ground—going from left to right, when facing the MQ-2 sensor. The module required 5VDC for power but was found to work even down to 3VDC. The analog pin, A_0, output a value between 0 and 1023, where higher values meant higher pollution. To make this sensor output to the control hub, five main components were needed: a circuit board, the smoke sensor, an ESP8266 microcontroller, a 3.3V voltage regulator to power the ESP, and an ESP8266 module serial interface transfer board Wi-Fi adapter to program the ESP.

Motion Sensor

The motion sensor used in the home alarm system project was a PIR (passive infra-red) motion sensor that had JST connectors. This motion sensor was a pyroelectric device, which could detect changes in motion by monitoring the infrared levels of the surrounding area. When a moving object changed the infrared levels of an area, the amount of infrared hitting the element changed, which then changed the amount of voltage generated in the circuit. This produced a change in state of the sensor. A Fresnel lens is a special filter used to concentrate the infrared signal for a more accurate sensor reading (PIR Sensor #555-28-27). This motion sensor does need boot-up time to work correctly and has to become familiar with its environment and the amount of infrared available in the area. Normally, this up-time takes about 10 seconds to allow the motion sensor to take in the surroundings. The motion sensor has the ability to sense motion up to about twenty feet away. Of course, the range can vary, due to the present environment.

This motion sensor can operate off of either 5 or 12 volts. There is a way to manipulate the sensor to run just off of 3.3 volts, but for the required project, 5 volts would be the supply voltage. The red wire was the power leg, the white wire was the ground, and the black wire was the alarm out. The alarm-out signal operated as a digital output with a push-pull configuration, meaning that a pull-up/pull-down resistor was not necessary when connecting to the ESP8266 microcontroller. The motion sensor would communicate with the webserver by the means of Wi-Fi with an ESP8266, which would be connected to the alarm pin of the motion sensor. When motion was detected, the alarm pin would send out a high signal to the ESP8266. It would then communicate with the web server node-red to send a text message to the user about the activation of the motion sensor.

Magnetic Contact Switch (Door Sensor)

Magnetic contact sensors operate on a very basic principle; the switch is either made as normally open (NO) or normally closed (NC). Either assembly allows for the sensor to send a variance when opened or closed to a data acquisition tool. The magnetic contact normally has an operating range of 15 mm or half an inch to the other half of the switch before a signal will be sent. The most popular design is a NC setup, where the switch will read open when the magnet half is not within range, meaning the double-ended wires will show an open circuit. When the magnet is near the switch, the circuit will be closed (normal operation).

To ensure that the ESP8266 reads a logical 1 when the switch opens, a pull-up resistor must be connected to the digital input responsible for reading the magnetic switch. When the magnet is nearby, the switch will be closed and the digital input will read a logical 0. The simplistic nature of the switch has made it extremely cost effective with some costing as little as $12; basic deployment for the device includes mounting the wired half of the device to a stationary surface and the other (the magnetic half) mounted to any sort of moving surface that is within the operating range of 15 mm or half an inch when closed. The standard deployment seen in most situations is mounting on doors and windows but could include any two surfaces that meet and part at the same area.

Bill of Material (BOM) and Comparison Against Existing Alarm Systems

Table 1 shows the BOM and comparison with other systems.

Table 1. BOM for the project.

Component Name	Quantity	Price (in USD)
MQ-2 Gas and Smoke 6pcs	1	$12.99
PR Sensor (JST)	1	$12.09
ESP8266 Adapter Modules	1	$6.99
MakerFocus 4pcs ESP8266 ESP-01	1	$12.99
ESP8266 Programmer	1	$10.99
Magnetic Switch 10pcs	1	$12.39
Total		$68.44

Although the authors, in this paper, only showcase one motion sensor, one magnetic contact switch, and one smoke detector, most products listed in the bill of materials come with multiple pieces. The current bill of materials allows for one additional magnetic switch or smoke sensor with Wi-Fi connectivity. At the time of writing, an online search for commercial home alarm systems showed costs generally ranging from $60-$600. Existing budget alarm system starter kits in today's market typically include a couple of motion sensors and roughly 1-6 magnetic contact switches, which is roughly comparable to the system proposed in this paper. When assessing existing home alarm systems on the cheaper end of the spectrum, it becomes clear that a monthly or annual subscription fee is typically required. Currently, standard subscription prices appear to range from $5 to $30 per month, significantly driving up the cost of operation over time.

In contrast, the home alarm system proposed in this paper does not require any monthly costs. The mobile web app and email notifications are free and self-hosted by the user, and the SMS notification service offers up to 100 free SMS notifications per month in the United States and Canada. Although motion detection and magnetic contact sensors are relatively standard components for home alarm systems in today's market, smoke-detection sensors do not appear to be commonplace in existing products. However, certain brands in today's market do offer smoke sensors as a separately purchased add-on sensor, further driving up total system costs.

Conclusions

The home alarm system demonstrated in the paper is relatively inexpensive, while being very effective on design. The design was showcased in several recruiting events. More research can be done on the range for the smoke detector and timing delay. This will save hundreds of dollars for many across the country who are paying large amounts of money to alarm companies. Figure 3 shows the built prototype; one of the co-authors demonstrating the developed prototype in a recruiting event and automatic texting/messages received when smoke is detected.

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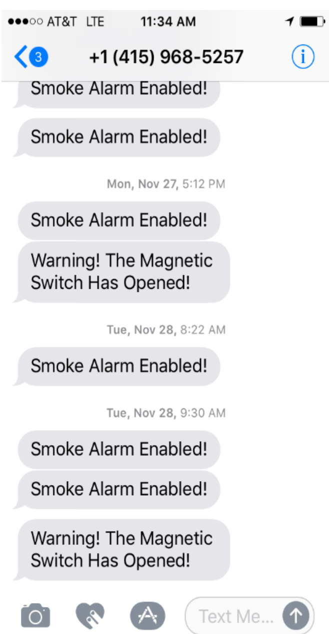
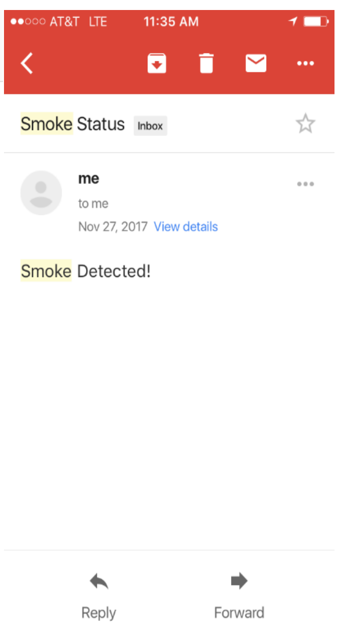
(a) The built prototype.

(b) Showcasing the developed prototype in a recruiting event.





(c) Text message received on smoke and break-in alarm.

(d) Email received on smoke alarm.

Figure 3. Home alarm system.

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Challenges and Future Directions for Extended Reality-enabled Robotics Laboratories During COVID-19

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Abstract

Laboratory sessions are essential to engineering education, especially for understanding abstract concepts. Expensive laboratory equipment and machines pose challenges to institutions aiming to offer accessible, hands-on learning opportunities. Moreover, the emerging trend of online engineering education faces critical challenges in how to satisfy laboratory learning requirements. With the rapid rate at which information and communication technologies advance the popularization of computer-embedded devices, education systems need to continuously innovate to promote education methods that leverage the latest technological features. Extended reality (XR) technologies enhance interactive virtual environments with an accurate resemblance to physical reality. These technologies enable students to examine the various bodies that compose the environment from different perspectives through simulated and sensory data. The principles of intermediate awareness and direct cognition are the essential advantages of immersive technologies. Learners are granted direct interaction without depending on second-hand accounts, which results in the regression of unique primary data. The application of extended reality in various paradigms, like problem-based learning, exploratory learning, and distance learning, has provided fertile ground to advance learning. Construction engineering education and coaching have adopted immersive technologies, including desktop-based immersive, 3D game-based, and modeling (BIM)-enabled XR. Specifically, XR can be considered as a pedagogical model for simulation-based learning. In this current study, five robotics laboratory sessions prior to and during COVID-19 were reviewed, and major challenges were highlighted. Following these comparisons, XR-enabled solutions were discussed to address these challenges and alleviate the workload for both students and instructors.

Introduction

Laboratory sessions are essential to engineering education, especially for understanding abstract concepts (Jagodziński & Wolski, 2015). The cost of laboratory equipment and machines poses challenges to institutions. Moreover, the emerging trends of online engineering education face challenges with regards to laboratory sessions. With the rapid rate at which information and communication technologies advance the popularization of computer-embedded devices, education systems need to innovate to promote quality education mediated by the latest technological features (De Mello & Gobara, 2014).

Extended reality (XR) technologies enhance interactive virtual environments with a seemingly accurate resemblance to physical reality. These technologies enable students to examine the various bodies that compose the environment from different perspectives through simulated/sensory data (Nubi & Vincent, 2020). The principles of intermediate awareness and direct cognition are the essential advantages of immersive technologies. Learners are granted direct interaction without depending on second-hand accounts, which results in the regression of unique primary data (Nubi & Vincent, 2020). The application of extended reality in various paradigms—such as problem-based learning, exploratory learning, and distance learning—has provided fertile ground for learning. Construction engineering education and coaching have adopted immersive technologies, including desktop-based immersive, 3D game-based, and modeling (BIM)-enabled Extended Reality (Nubi & Vincent, 2020). Specifically, XR can be considered a pedagogical model for simulation-based learning (Nubi & Vincent, 2020).

The COVID-19 pandemic has sped up the transformation phase for manufacturing laboratories. The constant threat of a partial or complete lockdown has pushed many educators to distance themselves from relying on physical laboratories and think outside the box on delivering hands-on experience through remote and virtual laboratories. XR technology, one of the top trending educational technologies (Bui, 2020) is one viable alternative to the high cost of laboratory equipment during and after the COVID-19 pandemic. In the context of learning, while virtual reality (VR) can be used as a complementary teaching method to further enhance learning experiences, augmented reality (AR) can provide a virtual extension to the physical learning space, enabling valuable yet physically impossible or time-consuming actions (Thiede, Posselt, Kauffeld & Herrmann 2017; Tsovaltzi, Rummel, McLaren, Pinkwart, Scheuer, Harrer & Braun, 2010; McCusker, Almaghrabi & Kucharski, 2018). AR has been considered as effective in education by making learning more interactive, dynamic, and engaging (Akçayır & Akçayır, 2017; Lee, 2012) as well as enhancing learning outcomes (Ong, Yuan & Nee, 2008). Prior research has found that AR improves learners' skills and knowledge in diverse science subject areas, including engineering education (Parras-Burgos, Fernández-Pacheco, Polhmann Barbosa, Soler-Méndez & Molina-Martínez, 2020). XR has been applied to enhanced learning in many different fields, such as projects and manufacturing processes (Liarokapis et al., 2004), electronic engineering (Martin-Gutierrez, Guinters & Perez-Lopez, 2012), architecture (Fonseca, Martí, Redondo, Navarro & Sánchez, 2014), and mathematics (Salinas, González-Mendívil, Quintero, Ríos, Ramírez & Morales, 2013).

Literature Review

Laboratories have been used for development, research, and education since the late 1800s in the United States. The first two categories focus on answering specific questions, determining design parameters, and extending the students' body of knowledge beyond what they have learned within the classroom. The third category, education, is critical to transferring theoretical knowledge, while gaining practical experience and skill sets (Balamuralithara & Woods, 2009), specifically in the fields of automation and robotics. Figure 1 shows how educational automation and robotics laboratories can be defined as purely hands-on, remote, and virtual modes.

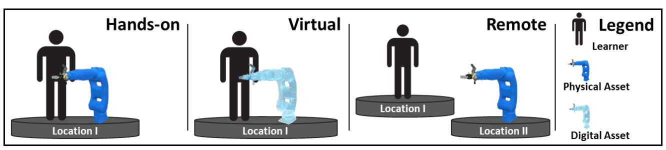


Figure 1. Categories of educational laboratories.

The categorization of educational laboratories is defined based on whether the learner and asset are co-located and whether the experiments are conducted using physical assets or digital replicas. Hybrid laboratories are created if any combinations among these categories occur. These hybrid laboratories are the result of the growing educational demands to combine the benefits of different modes (Viegas et al., 2018).

<u>Hands-on Laboratories</u>

Hands-on laboratories are designed to enable students to manipulate, observe, explore, and think about science using concrete materials, guided by a physically present educator. These laboratories can be further classified as onsite (i.e., built in a fixed location) and mobile (i.e., cars and trucks) laboratories. Lack of hands-on experience in manufacturing processes is one of the most crucial competency gaps in manufacturing education (Ssemakula, Liao & Ellis, 2006). The excessive costs associated with maintaining a modern manufacturing laboratory make it complex for educational institutions to provide challenging yet realistic experiences for students. Learning factories are one of the best realizations of hands-on laboratories in manufacturing education, where a practice-based engineering curriculum is integrated with analytical and theoretical knowledge (Lamancusa, Jorgensen & Zayas-Castro, 1997). Although learning factories have been proven to be capable of balancing theoretical concepts with physical facilities for product realization in an industrial-like setting, the high cost of setting up such facilities has led to non-uniform hands-on experience for the students in different universities (Ssemakula et al., 2006). Due to the high cost associated with hands-on laboratories, remote and virtual laboratories were gaining interest among educators even before COVID-19. The onset of COVID-19 and the introduction of Industry 4.0 technologies—such as industrial internet of things (IIoT) and XR—have significantly sped up the integration of remote and virtual learning laboratories.

<u>Virtual Laboratories</u>

Virtual laboratories are designed to teach students the fundamentals, while hands-on laboratories enable students to manipulate the systems and better understand the process of parameter tunning for systems. Virtual laboratories were developed as an online format and designed to reduce the costs associated with hands-on laboratories by reducing the equipment, space, and maintenance costs associated with hands-on laboratories. Virtual laboratories usually rely heavily on high-fidelity simulations and game engines to deliver realistic representations of physical systems.

Traditionally, simulations have been used in the design phase in manufacturing to save time and resources. Today, high-fidelity simulation models are used to better understand the behaviors of certain products and/or processes in different scenarios. High-fidelity simulations can support proof of concept and design, reduce integration costs by replacing physical assets with digital ones, shorten the design-to-delivery time, and optimize robotic and automated production systems. For example, Tecnomatix software's robotics and automation simulation solutions can be used to: 1) design complete work cells; 2) plan, simulate, and optimize robotic operation paths; and, 3) program robots and automation offline (SIEMENS, 2022).

XR is an umbrella term covering a spectrum of computer-generated immersive environments—such as VR, AR, and augmented virtuality (AV)—over the reality-virtuality continuum (Tunur, Hauze, Frazee & Stuhr, 2021). Virtual reality immerses users fully in an entirely virtual world created at the intersection of immersive technologies and high-fidelity simulations. While users lose their connections with the real world in VR, AR improves user experiences in the real world by augmenting virtual objects and superimposing information on the real-world environment. On the other hand, AV falls between VR and AR by augmenting real objects in virtual environments. Industrial automation and robotic operations training are ideal candidates for XR immersive training environments, due to the expense and safety considerations of physical robotic laboratories and has been the focus of multiple research studies.

Successful implementation of XR technologies in an education and training setting relies on achieving suitable levels of immersion and presence. Immersion is a user's perception of being present in a non-physical (i.e., VR) or pseudo non-physical (i.e., AR and AV) environment. Immersion is achieved by integrating technologies such as head-mounted displays, room scaling systems, haptic/tactile feedback, and smartphones into non-physical environments. These technologies exchange sensory input from reality with digitally generated signals, such as images and sounds (Freina & Ott, 2015). Presence is the subjective reaction of the user, due to experiencing immersion in an altered environment (Slater, 2003). If successfully implemented, XR environments orchestrate a harmonized exchange of information among its components (i.e., hardware and software) in order to provide immersion and presence for users. Though XR and industrial automation research and education have been a focus of prior studies, the Computing Community Consortium held a Content Generation for Workforce Training workshop in 2019 that identified limitations to current XR, VR, and AR systems. Limitations include: 1) understanding the level of realism needed for diverse types of training and 2) development of XR interaction and visualization techniques directly relevant to training (such as where and how tasks are to be performed).

Using XR devices to improve programming of manufacturing work cells based on industrial robots was investigated to visualize robot paths and execute path preplanning checks of a robotic cell (Neves, Serrario & Pires, 2022). A VR simulator for teaching robotics was developed and evaluated in which users were able to create trajectories while implicitly defining reference points. The VR simulator assists users in task execution, improving visualization, and reducing the time spent on the trajectory planning tasks (Dos Santos, Sangalli & Pinho, 2017). AR assisted a human operator to learn complex tasks in robot programming. Domingues, Otmane, Davesne, Mallem, and Benchikh (2009) presented a decentralized software and network architecture for collaborative teleoperation based on scaled mixed reality.

Remote Laboratories

Remote laboratories are set up to provide different avenues for sharing skills and resources among students in order to improve learning experiences (Cotfas, Cotfas & Gerigan, 2015). Remote laboratories deviate from hands-on laboratories due to the distance between the experimenter and where the experiment is taking place. Given recent advances in robot manipulators and tactile-feedback systems, remote laboratories are becoming more common in educational settings.

IIoT enables remote control of machines and robots through wireless communications and integration of low-cost sensors, hardware, software, edge computing, and storage systems (Gilchrist, 2016). In addition to facilitating advanced analytics and optimal operational decisions, IIoT can enable teleoperation, which represents the ability to operate equipment or machines from a distance (Fong & Thorpe, 2001). Telerobotic, a specific form of teleoperation, focuses on the remote control of a robot. Telerobotic, where human intelligence pairs with a robot's capabilities such as repetition, manipulation, and precision, can be achieved by utilizing a streaming wide range of data retrieved by sensors implemented in a robot's environment (Fong & Thorpe, 2001). Offline and/or real-time autonomy can be realized by processing these data. Although teleoperation's roots go back to the 1950s, the interest in teleoperations has surged significantly due to the COVID-19 pandemic as teleoperation platforms are designed for situations that are too dangerous, uncomfortable, limiting, repetitive, or costly for humans (Murphy, Gandudi & Adams, 2020). Remote laboratories are usually built upon teleoperation in manufacturing, where users learn to remotely operate a machine or robot in pseudo real-time. Another technology that improves the quality of remote laboratories is digital twinning. Digital twins are high-fidelity simulations that are connected to the actual assets through IIoT. In manufacturing, the main benefits of digital twins can be summarized as reducing risks as well as safer hands-on and remote training of operators (Hernandez-de-Menendez, Escobar Díaz & Morales-Menendez, 2020).

From a pedagogical perspective, hands-on, virtual, and remote laboratories have their own strengths and weaknesses. Hands-on laboratories not only foster interactions, collaboration, and socialization but also enable students to learn through trial and error. The main disadvantages of hands-on laboratories are limiting students to the laboratory, whether onsite or mobile, requiring active supervision, restrictive time budgets available to each student, and high maintenance costs. At the opposite extreme to hands-on learning, virtual learning relies on virtual representations of physical assets. As a result, the main advantage of virtual laboratories is their capability of promoting learning through trial and error in a safe environment, even with very limited supervision. Virtual laboratories eliminate restrictive time budgets, as students can go through the simulated experiments on their own schedules. In addition, virtual laboratories have much smaller maintenance and upkeep costs, as it is much more affordable to create a new digital copy of a robot than to buy a new one. The main disadvantage of virtual laboratories is their limitation in helping students gain necessary skill sets. The main advantage of remote laboratories is their capability to facilitate distant-learning programs. In addition, they can relax the restrictive time budgets of hands-on laboratories due to their flexibility. Although not as good as hands-on laboratories, in terms of educational effectiveness, they can provide better environments for gaining skills compared to virtual laboratories and deliver the same level of learning in terms of controlling robots and machines as hands-on laboratories. Similar to hands-on laboratories, one of the main disadvantages of remote laboratories is their high maintenance and upkeep costs. In addition, socialization usually is not practiced in remote laboratories (Hernandez-de-Menendez, Vallejo Guevara & Morales-Menendez, 2019). Both remote and virtual laboratories outperform hands-on laboratories in terms of accessibility, reproducibility, as well as safety.

Case Study and Proposed Approach

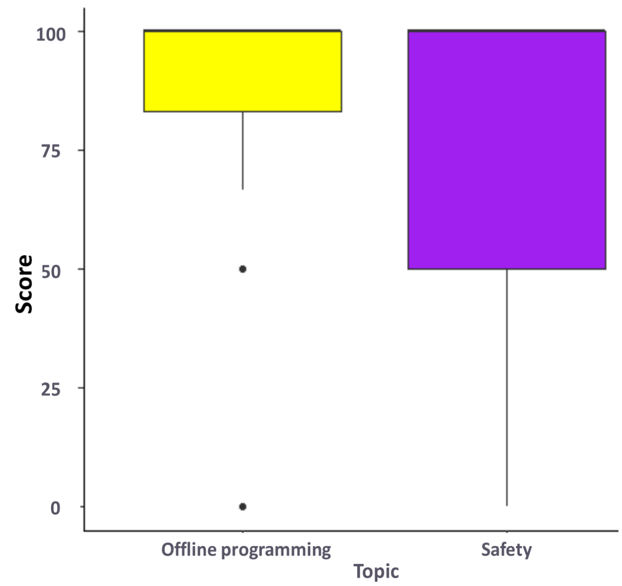
In robotics education, it is not only critical for students to handle hardware and equipment, but it is also a substantial learning goal of robotics programs. As a result, many efforts have been made to meet COVID-19 safety regulations, while providing a seamless transition from hands-on laboratories to virtual/remote activities without sacrificing learning quality. In this current study, students went through safety and offline programming modules in either hands-on or hybrid modes. While the second group (20 students) took these modules in a hands-on format, the first group (15 students) experienced these modules through remote/virtual hybrid laboratories. All other factors, such as materials covered in each module and instructor, were fixed in this experimental design. Safety and offline programming modules were selected to evaluate the impact of the hands-on versus remote/virtual hybrid laboratories on cognitive learning outcomes in terms of knowledge and skill gains, respectively. Figure 2 shows student grades over different topics and modes of learning.

Table 1 shows that the impacts of the topics and modes of learning were evaluated using the Welch Two Sample T-test. The mean performance of the students over different topics (offline programming versus safety) were compared, hypothesizing that there was a significant difference on the mean score of the student based on the topic of learning. Next, the mode of learning (hybrid versus hands-on) were studied. The hypothesis was that there was a significant difference on the mean score of the students based on their mode of learning.

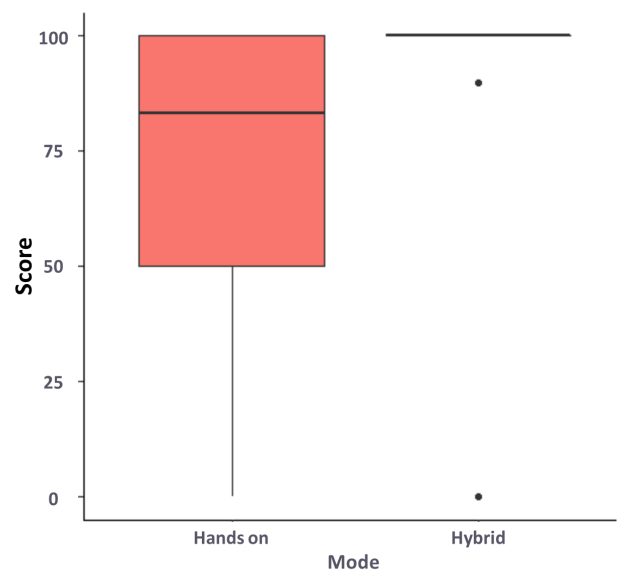
Table 1. Welch Two-Sample T-test of student performance on the topics and learning modes.

	T-value	Degrees of Freedom	P-value
Topic	0.070	28.0	0.944
Mode	3.292	67,7	0.001

Table 1 further illustrates that although the T-test failed to reject the first null hypothesis, studying the impact of the topic on student performance at a significance level of 0.05, it did reject the second null hypothesis. The results of the second Welch Two Sample T-test confirmed that the model of learning had a significant impact on student performance. Next, hypotheses considered whether the mode of learning could significantly impact both knowledge and skills gains. As a result, two additional Welch Two Sample T-tests were conducted where the first experiment focused on knowledge gain by comparing the impacts of modes of learning on student performance in the "Robotics Safety" module, while the second one concentrated on skill gain (i.e., psychomotor skills gain) through studying the "Offline Programming" module, as shown in Table 2.



(a) Student scores over topic (offline programming versus safety).



(b) Student scores over mode of learning (hands-on versus hybrid).

Figure 2. Student performance over topic and mode of learning.

Table 2. Welch Two-Sample T-test on student performance on offline programming and safety modules in hybrid and hands-on laboratory sessions.

	T-value	Degrees of Freedom	P-value
Skill Gain	3.0941	30.997	0.002
Knowledge Gain	1.4559	20.804	0.080

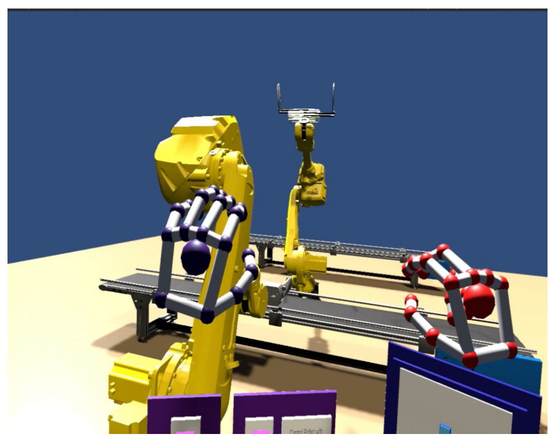
Offline programming has been a significant technological advancement for industrial robots/cobots, allowing quicker deployment at a lower initial cost. Offline programming has become an essential part of planning and designing any industrial robots or collaborative robotic system, as it significantly reduces programming time compared to traditional point-to-point programming. Comparing the performance of the students attending these two alternative laboratories illustrated that the students significantly (á=0.01) performed better when they learned through hands-on experience (p-value = 0.002 in a Welch Two Sample t-test with an approximate degree of freedom of 30).

The same design of the experiment was applied to the safety module. The Welch Two Sample t-test failed to identify any significant difference within the performance of the student groups taking the course with the hybrid and hands-on laboratories (p-value = 0.080 with an approximate degree of freedom of 20). While this analysis illustrates that there was no significant difference on knowledge gain among different laboratories, it highlights a significant gap in skill gain. To address this, an immersive learning alternative was proposed to reduce the gap between existing hands-on and distance learning approaches. Here, an immersive learning environment is presented, based on three levels of immersion using the Unity game engine.

Figure 3 shows how, in a VR–enabled laboratory, immersive technologies such as HTC Vive and Leap Motion were equipped with realistic, physics-based models and accurate gesture recognition algorithms to enable interaction with a teach pendant in the virtual world. This laboratory provided virtual scenes, where the user interacted with a virtual robot as well as a virtual teach pendant. The immersive technology required for this platform included HTC Vive and Leap Motion. HTC Vive utilizes multiple stations and trackers in order to provide room scaling capability. As a result, the physical movements of users can be directly translated to the virtual environment. Leap Motion was integrated into HTC Vive to model the movement of the user's hands in the virtual environment. These immersive technologies were integrated with the XR training environment, where the user made use of a virtual teach pendant with his/her virtual hands to interact with the virtual robots through a Mixed Reality toolkit. To provide a better sense of interaction, a replica or 3D-printed shell of a robot teach pendant, tracked with an HTC Vive tracker, was provided to the user. As a result, while the user was going through a module (e.g., jog a robot using joint and Cartesian coordinate systems) within the virtual environment, his/her hands experienced how to work with a teach pendant.

Although the proposed approach relies on VR technology, due to its affordability compared to AR, it is possible to implement similar laboratories using AR. In an AR-enabled laboratory, students can potentially rely on technologies such as Microsoft HoloLens II, smartphones, or tablets to visualize the augmented models of the robotic arm and use their hands to control a virtual teach pendant. In addition, the proposed virtual asset can be connected to the actual asset (the real robotic arm) to remotely control the physical asset.

(a) Subject wearing HTC Vive immersive head-mounted display, two controllers, and Leap Motion.



(b) Screen shot of the subject's point of view developed in Unity 3D game engine.

Figure 3. The components of the proposed VR-enabled laboratory.

Challenges and Future Directions

Although the proposed approach has the potential to enable hands-on learning experiences through remote/virtual hybrid laboratories, there are some challenges that should be recognized. Physics-based modeling is a major part of the proposed XR training environment, as it is responsible for a realistic representation of all assets (i.e., robots), whether dynamic or static. Unity game engine and PC developer's kit can be utilized to implement physics-based modeling components within the learning space.

- In real-time rendering, most common in interactive environments such as the case for this current study, the 3D images are calculated at an extremely high speed so that it looks like the scenes, which consist of multitudes of images, occur in real-time when users interact with the XR environment (Sherman & Craig, 2018). Unity's Sprite Renderer can functionalize the rendering process.
- Physics engines are software programs designed to enable computers to create real-world physics phenomena (e.g., gravity and fluid dynamics) and apply them to 3D objects in XR environments and/or other 3D renderings in order to visualize how those objects interact in the digital world. Any physics engine should be able to simulate a variety of physical systems (e.g., rigid body dynamics, soft body dynamics, fluid dynamics, etc.), apply those systems to 3D objects and environments, and work in tandem with other engines to create a cohesive experience. Unity's built-in 3D physics engine (i.e., Nvidia PhysX engine integration) can satisfy these needs.
- The last part of physics-based modeling is the robot kinematics engine, which is in charge of robot kinematics modeling and motion planning. These functions can be implemented via the integration of Robotics PC Developer's Kit, a powerful tool that enables high-performance communication of information and instructions between a PC, a robotic controller, and the Unity game engine.

One of the main benefits of this proposed remote/virtual hybrid laboratory setting is its capability in separating mastery of technical equipment from the acquisition of functional skills. To do so, it is critical to provide information and expose students to the equipment in an adaptable setting so that they have the freedom to learn about the equipment and skill sets at their own pace.

- The adaptation learning component utilizes deep learning algorithms to customize the immersive environment based on the user's personal behavior and related parameters. This customization includes calibration of user input signals delivered by the user interface and personalization of course materials based on real-time evaluation of the user's performance (Vaughan, Gabrys & Dubey, 2016). Recurrent neural networks, especially exogenous Long-short Term Memory (LSTM) models have shown excellent performance in time-series data analysis and signal processing, as those are the input format provided by the user interface (Guo, Lin & Lu, 2018). The adaptation learning component can be implemented via Unity ML- Agents toolkit (Nandy & Biswas, 2018), which is built on the open-source library TensorFlow (Abadi et al., 2016).
- The development of such an XR immersive and interactive training environment can be computationally exhaustive, as the environment should be dynamically updated to present real-time reactions to the user's continuous actions. In addition, no fixed frequency can be defined for the physics-based model reconditioning, given the dynamicity of robots. Updating the learning environment at a high frequency (i.e., every second) for all six modules may sound like a potential solution, but it is not computationally advisable as it puts too much pressure on the computational units and drains the battery life of the XR technologies.
- To address this issue, a logic module can be designed to implement Dynamic Data Driven Applications Systems (DDDAS) (Blasch, 2018). DDDAS not only relies on sensory data to monitor the performance of the system in real-time but also relies on these data to dynamically optimize the measurement process in a feedback control loop. To do so, the Logic module will employ a statistical algorithm such as an ensemble Kalman filter, Particle filter, or Bayesian models to optimize the run-time measurements of the user interface as well as the reconditioning of the developed physics-based model.

Implementation Challenges

VR headsets range anywhere from a few dollars to hundreds of dollars. Given the need for higher levels of immersion and interaction, the less-affordable VR systems are a better fit for the proposed platform. As a result, the implementation costs for the proposed virtual/remote laboratory setting could be a problem. If the purchase of the VR equipment is placed on the students, it may impact the quality of learning, specifically for the students from lower-income backgrounds. But it is notable that the proposed systems can potentially replace the need to purchase actual robots. A solution would be for the schools to invest in buying VR systems instead of robots and lend the VR setups to the students for remote laboratories.

VR may also cause cyber sickness, due to the sense of immersion and presence. Cyber sickness differs from motion sickness, as the user immersed in VR can be stationary and experience cyber sickness due to a compelling sense of motion caused by changes of visual imagery (Hale & Stanney, 2014). As a result, the higher the level of immersion and interaction, the more likely it is for the user to suffer from cyber sickness. But there are ways to alleviate or remove the potential of cyber sickness. Porcino, Clua, Trevisan, Vasconcelos, and Valente (2017) introduced guidelines to minimize cyber sickness levels in head-mounted display systems. Stauffert, Niebling, and Latoschik (2018) identified field of view, duration, and latency, while Kwok, Ng, and Lau (2018) recognized acceleration and navigation speed as the main factors impacting cyber sickness levels. Given these identified factors, a potential future research direction could be predicting the onset of cyber sickness.

Conclusions

Although essential, hands-on learning imposes some challenges on educational systems due to its high costs of implementation and maintenance. At the same time, the COVID-19 pandemic illustrated that there is a need to deliver the same quality of learning through remote and virtual laboratories. Comparing the current practices of remote and virtual laboratories to hands-on activities shows that although current practices can deliver the same level of learning quality, in terms of knowledge gain, the same cannot be said for skill gain. Comparing the performance of students attending these two alternative laboratories illustrated that those students significantly (α=0.01) performed better when they learned through hands-on experience (p-value = 0.002 in a Welch Two Sample t-test with a degree of freedom of 30) when skill gain was required. Here, the future of remote/virtual laboratories is pictured by relying on VR technology and deep learning.

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Ethics Cases and Technical Courses: Some Suggestions

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Abstract

In the two decades following the adoption of EC2000, ethics has assumed a prominent position in engineering and engineering technology education. While some schools farm out students to a philosophy department to experience a full course on professional or engineering ethics, others embed ethics in technical classes. Whatever the approach, at the end of the course, students should display behavior that reflects Criterion 3(4): "an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts" (ABET, 2022). In this paper, the author reviews the use of embedded cases to meet the ABET criterion. Specifically, the author explores reasons for using cases, resources, and cases appropriate for various curricula.

Introduction

Technology is a double-edged sword: on the one hand, it enhances the quality of our lives; on the other, it creates numerous questions regarding ethics and consequences. It is no longer sufficient to just design; the engineer must design with an eye to the implications of that design—social, physical, psychological, and financial. An apt example is social networking, which has conquered the world in the past decade. Initially conceived in 2003 as "a place for friends" (The death of MySpace, 2017), MySpace offered a convenient spot to share thoughts and artifacts with friends and relatives. Similarly, Facebook "helps you share and connect with the people in your life" (p.109, n.d.). Both were designed with benign, even beneficent, intent but have devolved over time. MySpace, in fact, no longer exists, and for some users, Facebook currently serves as a haven for social anomalies such as predation, racism, explicit violent images, and hate speech. What began as a significant and novel idea has gone awry.

The field of engineering, as it focuses on the creation and implementation of innovative technology, is particularly susceptible to these dual effects, especially if the emphasis is on production with little probative regard to consequences. Students aspiring to careers in an engineering field could benefit by preparing to deal with the impact of their design efforts by learning about ethical challenges and issues during their academic experiences. In the remainder of this paper, the author examines the use of embedded ethics cases in technical courses; specifically, exploring reasons for using cases, resources, and cases/issues appropriate for various curricula.

The Case for Cases

Case-based learning has a rich history, one that dates to antiquity. In higher education, case methodology in the U.S. can be directly traced to Christopher Columbus Langdell, dean of the Harvard Law School in the 1870s. Langdell wanted his students to extend their intellectual curiosity beyond memorization and recitation to careful thought and deliberation; that is, to "think like lawyers." Based on Socratic questioning and the use of primary materials collected by Langdell and published as course casebooks, the method initially was highly criticized by his colleagues, all of whom depended on lectures. However, Langdell's persistence paid off, and so many faculty converted to the "new" method that cases now form the pedagogical basis for all law schools in the U.S. (Weaver, 1991).

From its integration into legal education, case-based learning has spread to virtually every academic discipline, primarily because it offers so many benefits over the lecture method. Some of the major advantages to using cases are listed below; students learn how to

1. Develop their nascent critical analysis abilities, encouraged by the instructor's insistent poking and prodding (Garner, 2000)
2. "Teach themselves," since they are not reading textbook summaries and commentaries (Garner, 2000)
3. Think independently (Weaver, 1991)
4. Actively engage in course material (Boston University, n.d.)
5. Identify and cope with ambiguity (Boston University, n.d.)
6. Implement a decision-making process
7. Enhance communication skills and self-confidence (Nohria, 2021)

A final major advantage is that cases allow students to engage emotionally as well as intellectually with real situations involving real people and real consequences (Thiel, Connelly, Harkrider, Devenport, Bagdasarov, Johnson & Mumford, 2013). Emotional engagement occurs because cases are narratives, which are inherently engrossing because they help us to organize our experiences, adding "meaning and coherence." Jonathan Gottschall (2013, p.277), who has written widely about the impact of narratives, noted, "Humans live in a storm of stories" that chronicle our days and haunt our nights via dreams. They are also a familiar medium, since we are raised on stories, and hence students can easily relate to narratives. While sending students to the philosophy department for a stand-alone course is a convenient (and easy) way to deal with ABET's ethics proviso, seamlessly embedding cases in technical courses is preferable for a number of reasons. First, it encourages students to directly associate "engineering" and "ethics," rather than viewing the latter as something alien to their majors. For example, Grosz, Grant, Vrendenburgh, Behrends, Hu, Simmons and Walfo (2019) developed a program at Harvard called "Embedded EthiCS" for integrating ethics across the computer science curriculum. They used a "distributed pedagogy" to infuse ethics into all core courses, based on the precept that "Students can learn to think not only about what technology they *could* create, but also whether they *should* create that technology."

The overriding goal was to lead students to an understanding that "ethical reasoning is an expected part of a computer scientist's work" (Grosz et al., 2019), echoing sentiments expressed by Zandvoort, van de Poel and Brumsen (2000, p.298) some 20 years earlier: "The across-the-curriculum approach thus acquaints students with ethics from the start of their studies, so that they will come to perceive ethical considerations and ethical reflection as an integral part of engineering."

Second, using the case method also results in a positive change in class environment. Since discussion is a primary classroom technique when integrating ethics (Gill, 2011), instructors must be prepared with a thorough knowledge of the case and be willing to sacrifice lecture time to allow students a voice. Because most engineering and technology courses depend on a lecture-lab-test format, this is a major change both for students and instructors. But it has a number of side benefits, including noticeably higher engagement, enhancement of communication skills, and improved problem-solving prowess. Yet a third major reason for embedding cases is that the technique introduces a degree of ambiguity typically absent in technical courses. In examining situations through an ethics prism, students usually discover that there is no definitive right or wrong answer to a particular situation but a perhaps bewildering array of potential right answers. Their job is to choose the preferable solution, based on concerted research and deliberation.

Choosing appropriate cases can be a daunting task, due to an overabundance of resources available (see the following section), one that requires a few preliminary considerations, including pragmatic concerns such as class time available and course objectives. Big cases, such as Challenger, Bhopal, and Chernobyl, demand more discussion time than smaller cases, such as local occurrences or situations of lesser complexity. The ABET criterion suggests incorporating both types, generally categorized as microethical and macroethical, with microethical referring to the effects of actions on individual engineers (such as whistleblowing) and macroethical signifying those cases with significant social impact (Herkert, 2001). Regardless of choice, using real cases is imperative, as hypotheticals tend to be too simplistic. Real ethics is messy.

Resources

Fortunately for instructors, especially those new to the field of ethics, the internet is replete with cases. This section details a handful that are initial go-to sites for both novice and seasoned instructors.

Center for the Study of Ethics in the Professions (CSEP)
Located at Illinois Institute of Technology, CSEP (n.d.) is approaching its 50^{th} anniversary as an engineering ethics facility that offers many resources for teaching ethics. Of special note is the subject-arranged Ethics Code Collection that features more than 4000 codes of ethics from a variety of areas, dating from the 1970s to the present. In addition, the center sponsors a number of events and seminars. Of particular note is its "ethics across the curriculum" NSF-funded series, which is invaluable for instructors wishing to integrate ethics into their technical courses.

Markkula Center for Applied Ethics
The Markkula Center at Santa Cruz University, https://www.scu.edu/ethics, has a wealth of cases and teaching resources, in addition to analytic articles. Cases are arranged by subject, relatively short, and easily accessible.

Murdough Center for Engineering Professionalism
Texas Tech's Murdough Center, https://www.depts.ttu.edu/murdoughcenter, offers dozens of cases spanning the gamut of engineering disciplines. Each case includes a presentation of the facts, alternate solutions, survey results, and forum comments. The center also sponsors podcasts, seminars, workshops, and professional development courses.

NSPE Board of Ethical Review (BER)
Since 1958, the NSPE's ethics board has catalogued and archived cases that surface for BER review, available to a general audience at https://www.nspe.org/resources/ethics/ethics-resources/board-ethical-review-cases in a searchable database. Each case includes an anonymized recitation of case facts, a summary of the BER's discussion, references to appropriate code provisions, and the board's conclusions. The NSPE Ethics Reference Guide includes both a comprehensive listing of cases by board opinion and a code of ethics index (NSPE, 2021).

National Institute for Engineering Ethics (NIEE)
Purdue's School of Engineering Education has sponsored the NIEE, https://www.niee.org, since 1988. In 2001, it was integrated into the Murdough Center. The institute is well known for its videos tailored for classroom usage: *Gilbane Gold* (1989), *Incident at Morales* (2005), *Ethicana* (2009), and *Henry's Daughters* (2010).

Online Ethics Center for Engineering and Science (OEC)
This virtual center, https://onlineethics.org, is the brainchild of esteemed ethicist Caroline Whitbeck and is a comprehensive collection of cases, teaching resources, curated conference presentations, and various special lectures. It also

includes a section on assessment and evaluation that is especially useful for classroom teachers who wonder if their ethics efforts have tangible, measurable effects.

Curricula-Appropriate Cases

Cases tend to exhibit common ethics themes. In general, there are clusters of issues across broad categories: some deal with professional behavior (obligations to employers, clients, the general public); others concern general issues in engineering (safety, risk assessment, design). Each engineering discipline, however, tends to feature issues peculiar to that field. Regardless of the case, researchers should extend their searches to examining the site's sponsoring organization and author, as some cases exhibit patently false or misleading information. The McDonald's spilled coffee case provides an appropriate example: in 1994, 79-year-old Stella Liebeck made headlines when she sued the McDonald's Corporation for millions of dollars for burns to her groin sustained when a hot cup of coffee spilled in her lap.

Many sites poke fun at the case, calling Stella a stupid old woman who didn't know how to use a cupholder (her car had none), and one even described the "Stella Award" for the year's stupidest lawsuit (Cassingham, 2007). Missing is significant information: Stella is but one of more than 700 who reported being burned by McDonald's coffee (served at 20-30°F hotter than typical restaurants and 35°F hotter than a home coffeemaker) and having received third-degree burns that in some spots went to the muscle layer; she tried unsuccessfully to have McDonald's simply cover her medical costs, which involved skin grafts and other extensive treatments along with her recovery that lasted about two years (Enjuris, 2022). The Stella Award is a fabrication, and McDonald's, in fact, launched a rigorous campaign to rebut, defame, and humiliate Stella (Enjuris, 2022). Obviously, ethical consideration of any case must be based on facts, not prevailing public opinion on random blog posts.

<u>Biomedical</u>
As one of the newer and rapidly evolving fields, biomedical engineering combines engineering and the biological sciences "to improve healthcare by developing engineering solutions for assessing, diagnosing, and treating various medical conditions." Applications include "medical imaging, prosthetics, wearable technology, and implantable drug delivery systems" (Grove, 2019). It is interdisciplinary in nature, and ethical issues include not only typical engineering issues but those of science as well, which frequently have significant import. In addition, crisis management is more prevalent in this field than in others, as the emergence of COVID-19 illustrates. The pandemic presented a global crisis that coalesced around three major ethical themes: "1) The dilemma of identifying criteria for the allocation of medical devices; 2) Responsibilities of science and technology; and, 3) Inadequacy of regulations and norms, which lack universality" (Maccaro, Piaggio, Dodaro & Leandro Pecchia, 2021).

Cases in this field can involve individuals, industries producing devices such as pacemakers and artificial hips, and research facilities, both industrial and academic. The CSEP site (search for "Biomedical Engineering Ethics") offers a very useful, albeit slightly dated, bibliography of centers, journals, and articles that detail numerous cases and issues, such as organ transplants, single-use devices, human rights, obligations to patients, and legal considerations (CSEP, n.d.). Cases involving medical devices are appealing to engineering students, at least given anecdotal evidence. Lewis, Van Hout and Huang-Saad (2010) recount their experiences looking at two companies producing faulty implantable defibrillators, reporting that only one student team out of 30 recommended recalling the devices (the real outcome); the other teams were evenly split between notifying the FDA and notifying physicians. Students rated the discussions to be very satisfying and enlightening, underscoring the importance of small-group discussion as a pedagogical technique.

<u>Civil</u>
Civil engineering in and of itself is a collection of sub-disciplines, including structures (buildings, bridges, dams), transportation, environmental/public works, geotechnical, and construction, to name but a few. The possibilities for failures stemming from ethical considerations are vast. Smaller cases work well for an introduction to ethics in particular fields. In civil engineering, numerous university websites have descriptions of easily manageable brief cases: Texas A&M, the Markkula Center at Santa Cruz University, University of Pittsburgh, University of Delaware, and University of Buffalo. And the ASCE's *Civil Engineering Magazine* publishes a monthly column, "A Question of Ethics," that recounts situations investigated by its Committee on Professional Conduct. Larger cases include structural, dam, and bridge collapses. An in-depth look at the Hyatt Regency Walkways Collapse (1981), deemed the worst structural failure in U.S. history (Levy & Salvadori, 1992), reveals violations of professional conduct that caused the death of more than 120 people. Examining the St. Francis Dam collapse (1928) exposes the origins of professional registration for engineers, as the autonomy given to William Mulholland as sole designer, was directly responsible for the deaths of up to 1000 people and the destruction of several small towns and hundreds of acres of fertile agricultural land (Dyrud, 2013).

<u>Computers</u>
Cases in computer engineering involve both hardware and software. Cases in the former tend to be cross-disciplinary and also involve mechanical engineering concerns, such as autonomous technologies (self-driving cars) and the Volkswagen emissions controversary. Others are squarely tethered to software: privacy and data management issues, AI, surveillance, and especially facial recognition technologies. Assigning responsibility when something goes awry is vexing, as teams, rather than individuals, engage in design. Loui and Miller (2007) noted the example of the Therac-25

case from the mid-1980s. The machine, used for cancer radiation treatment, overdosed six patients, three of whom died due to software-based errors. Who, they ask, is responsible? Several possibilities exist: machine operators, software developers, the manufacturer, systems engineers (Loui & Miller, 2007). A seminal site for instructors is ComputingCases.org, which features a number of large cases, such as Therac-25, smaller cases, and several very useful links. In addition, the Public Sphere Project, sponsored by Computing Professionals for Social Responsibility (cpsr.org) has literally hundreds of cases categorized by "patterns."

Electronics

Rarely, notes Charles Fleddermann (2000), do typical engineering ethics cases involve electronics, leading to a lack of student interest and a paucity of resources. This does not indicate, however, a general lack of interest or cases in that field. Many electrical engineering concerns are subsumed by other fields, particularly computer science. And electrical failures tend to be much less dramatic than a building collapse, resulting in a lack of publicity when failure occurs. In addition, IEEE is attempting to overcome a decidedly anti-ethics bias in its governing groups between 1996 and 1998, when the society withdrew support of ethics-related activities (Elden, 2016). In this particular field, the professional organization has substantial clout, as IEEE is the largest professional society in the world.

Prior to that time, IEEE was actively engaged in ethics, which included an Ethics Committee to review cases and an Ethics Hotline, an anonymous reporting mechanism. Versions of the EC cases are available in Elden (2016) and Unger (1999) and include smaller cases involving engineers dealing with intensive care equipment failures, airbag safety, and wafer stability. Larger cases include the flawed Intel Pentium 5 chip, which caused incorrect calculations. At first, Intel responded that it would replace chips if users could show a demonstrated need. After media publicity, the company agreed to replace all of the chips (Fleddermann, 2000). The larger issue is an important one for users: should companies report flaws to consumers?

Another large case involved the BART system in the San Francisco mass transit commuter rail, one the few cases in electrical engineering involving whistleblowing: three BART engineers discovered a glitch in the innovative automatic train-control system that caused trains to overshoot their stations. Unable to persuade BART management of the problem, they approached BART's board of directors. While the engineers were dismissed, the problem was repaired (Fleddermann, 2000), primarily due to the public safety issues involved. Like computers, electronics are integrated into our lives: we all use electronic devices for everyday living, whether they be toasters or complicated electric vehicles; so it behooves electrical engineering instructors to integrate ethics into their courses to ensure that their students receive the same benefits from that instruction as do others enrolled in engineering programs.

Mechanical

The field of mechanical engineering has some spectacular disasters on the record: the DC-10 cargo door latch failure and the Challenger. Indeed, these are now part of the standard litany of engineering ethics cases presented in classrooms across the nation. Cost is another major issue in this field, one that often leads to conflict with management. The "Ur" case is the Ford Pinto, which management was hell-bent to rush into production (25 months instead of the standard 43) and keep the retail price under $2000. Safety was not a concern with CEO Lee Iacoca, who famously stated "safety don't sell"; he focused instead on a cost-benefit analyses that set the cost of a human life at $200,000 and predicted that settling lawsuits would be cheaper than fixing the problem, with solutions ranging from $1 to $11 per car. Engineers, who were fully aware that the gas tank placement could rupture in read-end accidents, were reluctant to speak up. Eight years later and after 500-900 burn deaths, Ford Motor Company finally started settling suits out of court, noting that juries were "too sentimental" and awarded high-dollar damages (Dowie, 1997). The callousness displayed by Ford management is truly shocking. As consumers, we believe that companies would not deliberately market a product that endangers users.

Smaller cases deal with issues like product liability and are readily available on the internet, for example, on sites such as a listing of cases on the supplemental CD for Harris et al.'s *Engineering Ethics: Concepts and Cases* (Wadsworth, 2000). For instructors who prefer a quantitative approach to ethics, Texas A&M (1995) developed a number of mathematically based cases for an NSF grant.

Accentuate the Positive

While most ethics cases tend to focus on negative actions and outcomes, such as code violations or harm inflicted upon persons or entities, it is helpful to temper criticism with stories of courageous engineers and scientists who chose to do the right thing. These include Roger Boisjoly, a mechanical engineer and whistleblower in the Challenger disaster; Fred Cuny, a civil engineer and disaster relief worker who specialized in humanitarian enterprises and disappeared in 1995 during the Chechnya conflict; William LeMessurier, the structural engineer for New York's Citicorp Tower, who acted on questions from students and managed to prevent the collapse of the structure in downtown Manhattan (OEC, 2022); and, Cate Jenkins, an EPA scientist who openly challenged the EPA's assessment of air safety in Manhattan following the 9/11 disaster, accusing several agencies of data manipulation (Jenkins, 2007).

Conclusions

In this paper, the author has included numerous examples in order to persuade readers that integrating ethics content via cases into technical courses is a painless way to educate students about their ethical duties and responsibilities without sacrificing technical content. In addition, this technique circumvents a number of institutional or personal obstacles, such as

1. The curriculum is already full, and there is little room for ethics education,
2. Faculty lack adequate training for teaching ethics,
3. There are too few incentives to incorporate ethics into the curriculum,
4. Policies about academic dishonesty are inconsistent, and
5. Institutional growth is taxing existing resources (Walczak, Finelli, Holsapple, Sutkus, Harding, Carnegie Mellon University Janel Sutkus & Carpenter, 2010).

All of these are easily overcome, and for faculty concerned about their own ethics education, talking with other faculty in appropriate departments, such as philosophy, combined with self-study, can overcome perceived deficiencies. And once faculty experience the engagement and obvious enthusiasm that students display in response to an ethics problem, concerns of the past disappear. A political science professor at Stanford University, Rob Reich, stated, "The profound consequences of technological innovation…demand that the people who are trained to become technologists have an ethical and social framework for thinking about the implications of the very technologies that they work on" (Wykstra, 2019). Technology has insinuated its way into virtually every aspect of our lives, influencing how we interact with others, how we spend leisure time, how we perform at work, how we think—basically, who we are. Engineering education demands a simultaneous study of ethics to acquaint students with professional expectations regarding workplace behavior.

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Biography

MARILYN DYRUD retired in 2017 as a professor emerita in the Communication Department at Oregon Institute of Technology, where she taught classes in writing, speech, rhetoric, and ethics for four decades. She received her BA in 1972 from the University of the Pacific in Stockton, CA, and her graduate degrees from Purdue University: MA in 1974 and PhD in 1980. She became involved in engineering education by joining ASEE in 1983 and is currently active in two divisions: Engineering Ethics and Engineering Technology. She is an ASEE fellow (2008), winner of the James McGraw and Berger Awards (2010, 2013), the communications editor for the *Journal of Engineering Technology*, and the ETD mini-grant coordinator. She has been involved with IAJC for a dozen years, serving as a manuscript reviewer, originality checker, proceedings coordinator, and conference speaker. Dr. Dyrud may be reached at Marilyn.Dyrud@oit.edu

Increasing U.S. Competitiveness with Entrepreneurial-Minded Postdocs in High-Tech Startups

Teddy Ivanitzki, American Society for Engineering Education; Rashida Johnson, American Society for Engineering Education

Abstract

Studies have shown that in the U.S., women, African American, and Hispanic American entrepreneurs secure a disproportionately tiny fraction of venture capital funding, especially when compared to their representation in the population. This investment discrepancy is not only socially unjust, but it also deprives the U.S. of the advantages in discovery and global competitiveness that could stem from these groups' increased participation in innovative sectors. This is particularly true within transdisciplinary startups, like smart energy or nanomedical technologies, all of which increasingly require cross-disciplinary experts. Every new entrepreneur in these fields experiences challenges in finding adequate support. These challenges exist at a time in the 21st century when U.S. innovation is facing unprecedented pressures in competition for primacy. In 1960, the U.S. research and development (R&D) expenditure for defense and private industries was approximately 69 percent of global spending on R&D. By 2016, however, the U.S. share of global R&D expenditure had decreased to just 28 percent, due to China's technological advances. If this trend continues, China's R&D expenditure, measured by gross domestic product (GDP), will outperform that of the U.S. by 2030.

To ensure that the U.S. remains a world leader in R&D, the National Science Foundation (NSF) launched the Small Business Postdoctoral Research Diversity Fellowship (SBPRDF), followed by the Innovative Postdoctoral Entrepreneurial Research Fellowship (IPERF). Both facilitate the professional development of underrepresented postdoctoral research fellows by offering them invaluable experience within research and technology companies. In this paper, the authors provide a pathway for enhancing diversity on the startup and entrepreneurial landscapes, improving opportunities for researchers from underserved groups, and increasing the number of highly competent entrepreneurs within the U.S. STEM community. The startup companies involved in the fellowship program, which are also supported by NSF, were made up of a variety of new, multidisciplinary, and rapidly evolving STEM fields that were unknown just a few decades ago.

Introduction

In 1960, the U.S. R&D expenditure for private and defense industries comprised 69 percent of worldwide spending on R&D (CRS, 2018). By 2016, however, the U.S. share of global R&D expenditure decreased to only 28 percent (CRS, 2018), due mostly to China's substantial growth and advances. Should this trend continue, China's R&D expenditure, measured by gross domestic product (GDP) will eclipse that of the U.S. by 2030 (CRS, 2018). In order to remain competitive and uphold its leadership in innovation, the U.S. needs to use all of the country's available talent. In the past, only privileged entrepreneurs were able to participate in high-tech startups. As a result, the National Science Foundation (NSF) started programs with the aim of engaging underrepresented groups in a variety of entrepreneurial startups.

In FY 2013, the last year data were available, the Small Business Administration (SBA) awarded 5159 Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) Phase I and Phase II grants totaling more than $2.5 billion, as per the SBA Annual Report (2013). On average, the SBA awards more than 5000 grants to entrepreneurs every year, totaling $3.5 billion (SBA, 2020). The same 2013 SBA Annual Report disclosed that only about 15 percent of this funding was awarded to women and underserved minority groups, even though those groups represented approximately 50 percent of the U.S. population. For comparison, this is a significantly lower percent than science and engineering (S&E) doctorates awarded to women and underrepresented groups in 2013 (NCSES/NSF, 2020). Such funding at a level of 15 percent does not reflect the capacity or talent of the more than 90,000 underrepresented scholars who earned S&E doctoral degrees between 2005 and 2015 in the U.S. (SED/NSF, 2016). This underfunding trend led Congress to allow eligible agencies to use three percent of their small business grant budget, set aside for administrative purposes, to support underserved groups under the SBIR/STTR Reauthorization Act of 2011. As a result, many agencies use this funding for outreach to underserved groups.

The private sector tells a similar story. Diversity VC, a nonprofit partnership promoting diversity in venture capital, reported in 2019 that, according to a comprehensive survey by Azevodo (2019) of around 10,000 business founders receiving venture capital backing, only nine percent were women and a mere one percent were Black. According to former SBA Administrator Maria Contreras-Sweet, "Only 1 percent of VC capital flows to Hispanic or Black entrepreneurs. Does anyone honestly believe these communities are the source of just 1 percent of our best business ideas?" Researchers who study this issue assert that women and minorities are not receiving investments because these underrepresented groups are not connected to venture capital networks, and do not know where to look for new opportunities.

Solving the Problem on the Horizon

In order to accelerate innovation, increase participation of underrepresented minorities in new startups, and ensure U.S. competitiveness in the global economy, NSF introduced the Small Business Postdoctoral Research Diversity Fellowship (SBPRDF) program in 2011 (Tull, 2018). NSF selected the American Society for Engineering Education (ASEE) to manage the fellowship. The SBPRDF provided an opportunity to measurably increase the participation of underrepresented minorities in small business research and high-tech entrepreneurship, thereby accelerating U.S. innovation. Throughout the grant cycle for the SBPRDF, the program administrators and ASEE conducted surveys regarding program effectiveness so that the next iteration, NSF's Innovative Postdoctoral Entrepreneurial Research Fellowship (IPERF) program, could expand what worked and correct what did not.

In the first iteration of the program, the SBPRDF invested in a total of 79 S&E PhD recipients, placing them in research positions at eligible NSF Phase II SBIR companies. ASEE facilitated these placements. These individuals acquired real-life entrepreneurial research experience, bringing the latest innovative theories and techniques from the academic community to the country's entrepreneurial technology sector. By working with cutting-edge startup companies, where research and development are accomplished within a framework of expected business outcomes and constraints, research fellows learned to work in multidisciplinary teams and apply their academic expertise to realize products in a globally competitive environment. The program aimed to establish mutually beneficial relationships between the companies and the fellows.

The Phase II SBIR program companies received help from these highly talented postdoctoral research fellows to accelerate their business enterprise; at the same time, underrepresented groups such as women, African Americans, Hispanic Americans, American Indians, and Hawaiian/Pacific Islanders received valuable experience in small business innovative research. Since the SBPRDF program's inception in 2011, ASEE's involvement has brought much success. However, ASEE realizes that opportunities exist for the program not only to better serve its fellows' professional development, but also to address minority-owned firms' lack of participation in research supporting high-tech entrepreneurship and the federal government's needs. Historically, there have been almost no high-tech entrepreneurial startups owned by underrepresented minorities, due to lack of minority access to higher education, nonexistent financial support by conservative venture capital firms, and basically no additional support by previous governmental agencies or programs.

The SBPRDF program placed 79 fellows in 77 different Phase II Active SBIR companies from 2011 to 2018. Program participant surveys conducted in 2014 and 2019 (Tull, 2019) found many positive outcomes. One of these was that the proportion of underrepresented groups in the fellowship applicant pool and the proportion of those selected exceeded those among newly graduated engineering doctoral students. Based on the final SBPRDF report (Tull, 2019), among 79 fellows, women and underrepresented minorities represented more than 40 percent of program participants. Additionally, 40 percent of the SBIR host companies ultimately hired their fellows as full-time employees for performance testing and prototype commercialization. Seventy-two percent of the postdocs noted that the SBPRDF fellowship gave them a competitive edge in the job market, with some further reporting that they gained valuable grant writing and business experience. Of all the fellows in the SBPRDF program, 43 percent of the participants were offered employment by their host companies, and 84 percent believed that the fellowship experience enhanced their professional qualifications.

Figure 1, based on results of a longitudinal survey conducted in December of 2021 of 50 SBPRDF fellows who left the program more than three years prior, shows that even though 40 percent were hired by the host companies, only a tiny fraction of five percent were still working at those startups. Many others found jobs either within the larger industry (30 percent) or other startup companies (30 percent). The remaining fellows went into various governmental labs or administration positions. There were three primary reasons cited by the fellows for not being offered employment by their host companies.

1. The company did not have sufficient financial resources to extend an offer of permanent employment to the fellow. Interviews with departing fellows described a correlation between the size of the company and funding available to the fellow. In small businesses that employed fewer than five people, the funding period was relatively short, especially for employees commanding salaries in excess of $80,000 per year; however, in enterprises with more than 10 employees, funding was more readily available.
2. The fellow was not interested in pursuing a career with the host company.
3. It was too early for either the fellow or the host company to make an employment decision.

An especially notable survey finding was the increase among participants who reported, three years after the program ended, that their participation in the program was a positive experience. While most of the fellows—72 percent—reported a positive experience immediately following the program, even more came to see the value in it as time went on. Three years later, 90 percent of the participants described their experience as either "extremely valuable" or "valuable."

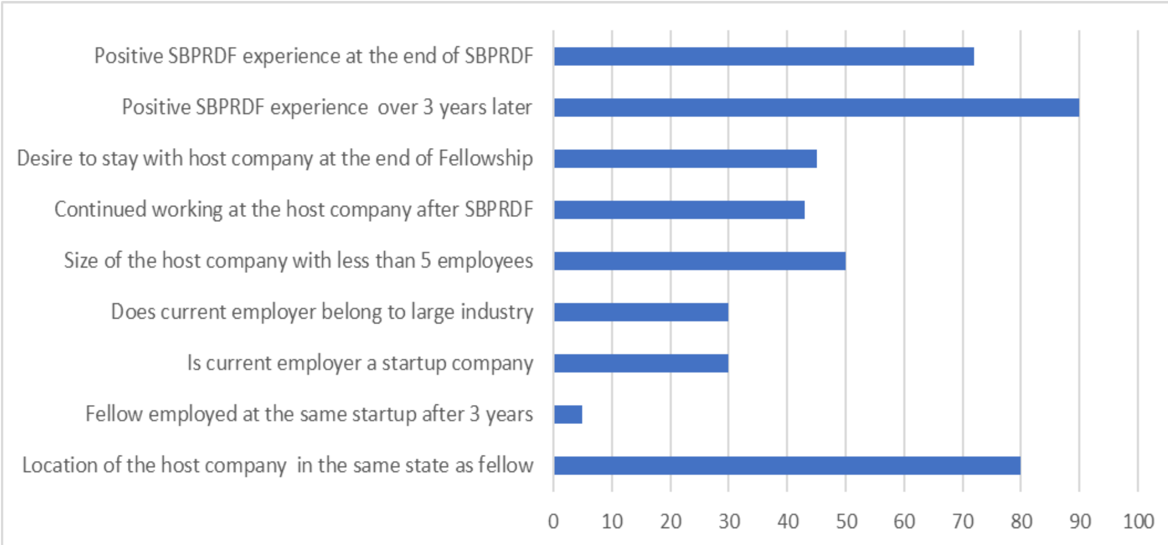

Figure 1. SBPRDF survey immediately after the fellowship and three years later.

In 2019, the program hired independent evaluators to conduct a survey to understand the financial impacts of fellowships on the participants. About half of the fellowship host-company mentors reported that they offered stock options to their fellows. More than 70 percent of those mentors who did not give fellows stock options reported being willing to do so in the future in hopes of attracting a postdoctoral fellow to their company. One third of the fellows said they accepted stock options and/or other deferred compensation when hired by their company. Fifty percent of the fellows who received stock options reported that they were able to exercise their options and participate in a liquidity event.

The evaluators also noted that, while the SBPRDF program has been quite successful, there is still room for improvement. The evaluators recommended that the SBPRDF be more engaged with the fellows both during and after the fellowship. The program should also facilitate the formation of a community engaging current fellows and program alumni. Additionally, fellows reported that expectations for the fellowship could and should be better laid out, and that fellows wanted opportunities to meet and learn from the experiences of other fellows. Those issues were explicitly addressed in the recently awarded grant proposal entitled "NSF Innovative Postdoctoral Entrepreneurial Research Fellowship (IPERF), NSF #1853888" in 2019. Based on additional programs developed specifically for IPERF, the ASEE team was able to improve both the program quality and fellows' satisfaction levels. Details will be published at the end of IPERF in 2023.

The project team focused on developing intensive, low-cost online communications rather than person-to-person engagement. The team and the fellows also discussed and agreed on the most important training topics to be offered to fellows. These topics included: i) how to start a business, startup prerequisites, and how to influence others with their own ideas; ii) the ABCs of seeking SBIR/STTR research funding and how to find the most important funding websites; iii) an Introduction to Intellectual Property (IP) for High-Tech Entrepreneurially Minded Postdocs; iv) management, mentors, and money: decoding the chasm between invention/research and product commercialization; and, v) managing the pressure and stress of a startup environment during a pandemic.

ASEE did offer one-on-one, face-to-face consultations via computer to fellows looking for guidance on their next career steps, especially pertaining to entrepreneurship; approximately 15 hours of counseling were delivered. The consultants came from the venture capital field, and a large portion were from underrepresented groups. Topics of these consultations included mentoring and commercialization aspects, transitioning from academia to startup, time management/prioritization, and how to manage work-life balance, especially during a pandemic.

The IPERF host companies signed up and committed to offering a mentor from each of their companies and to collaborate closely with their accepted fellow during the fellow's postdoctoral appointment as a condition of participating in this program. Additionally, every six months, each mentor company would deliver a report summarizing the fellow's progress. The progress report would include assessments of the fellow's research project, a list of joint publications by the fellow and mentor company researchers, and areas of possible future collaboration with the fellow. ASEE has been evaluating these reports and giving informal feedback to the fellows for improvement, especially if fellows were seeking a second-year award extension.

Ethnic and Racial Distribution in SBPRDF versus IPERF

Both cohorts surveyed, the SBPRDF and IPERF, were composed of underrepresented minority (URM) groups, including African Americans, Hispanic Americans, American Indians, Alaska Natives, and Pacific Islanders. Table 1 shows URM/W, which is the sum of all URM men and women plus non-URM women in the program, and represents the level of underserved populations; URM+W represents the number of URM women in the program, and URM+M denotes the number of URM men in the program. Finally, "W" represents the sum of all women in the program as of September 2021. The above definitions follow the National Center for Science and Engineering Statistics (NCSES) report (NCSES/NSF, 2019), as an indicator for underserved populations in the U.S.

Table 1. Racial distribution in the grants versus average population in the U.S. (NCSES/NSF, 2019).

	URM/ W	W	URM	URM+ W	URM+ M
IPERF FY 2021	72%	49%	32%	9%	23%
IPERF FY 2020	65%	43%	39%	8%	22%
SBPRDF Final	56%	37%	27%	5%	21%
U.S. population average	67%	52%	33%	17%	16%

ASEE's overarching goal of increasing the participation of women and underrepresented groups in the IPERF program has thus far achieved great success. In two years of outreach activities, 48 fellows joined the IPERF program. More than 70 percent were women or held URM status. The remaining 20 percent were of Middle Eastern or Asian descent (not defined as underrepresented minorities). This is a significant increase over the previous SBPRDF grant project, which was composed of 56 percent URM/W. The ASEE team attributes the success in IPERF versus SBPRDF in reaching more diverse candidates to an increase in advertising in dedicated markets, such as Historically Black Colleges and Universities (HBCUs), the Society for Advancement of Chicanos and Native Americans in Science (SACNAS), and the National Postdoctoral Association (NPA).

The ASEE team also required a diversity statement with the fellowship application, which was meant to illustrate the candidates' involvement in supporting underrepresented groups. ASEE evaluated each of the candidate's applications based on their commitment to serving underrepresented populations in STEM. Both factors—dedicated advertisements and diversity statements—contributed significantly to the increased success in engaging URM/W groups in IPERF versus SBPRDF. The team's explorative research of multiple STEM fellowships in the U.S. revealed significantly lower URM participation in other programs, with the exception of some medical fields in which only women were adequately represented.

Conclusions

The IPERF project has thus far resulted in increasing the participation of women and underrepresented groups in high -tech entrepreneurship, as one of the first of such successful and supportive activities in the U.S. No other or similar programs or grants in STEM represent such high participation of underrepresented groups among their cohorts. To the authors' knowledge, only the IPERF program has shown such success thus far. Both factors of frequent, dedicated advertisements and diversity statements by applicants contributed significantly to the increased success of engaging URM/W groups in IPERF. The fellows' engagement in entrepreneurial activities should help increase the socioeconomic status of those individuals and of groups often left on the lower rungs of the economic ladder. Through IPERF, these highly educated, theoretically oriented fellows can learn on-the-job, practical skills of modern entrepreneurship.

They will have the choice of either staying and joining the high-tech startup, launching their own businesses after their fellowships, or even joining industry labs as experienced entrepreneurs. The professional development and education they receive will be invaluable both to them and to the overall goal of closing the diversity gap in high-tech entrepreneurship and leadership in the U.S. Every fellow leaving the program is equipped with needed skills and insights to follow the path of entrepreneurship, contributing to a healthy and diverse balance of successful entrepreneurs in the U.S. The IPERF program initiated by NSF is worthy of duplicating within every governmental agency and of publicizing across the U.S., especially within the venture capital community, which will profit tremendously from the breadth of innovative and highly trained young entrepreneurs, ready to develop and deliver highly competitive and world-changing products to the global economy.

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Biographies

TEDDY IVANITZKI is one of ASEE's directors within the Fellowships and Research Opportunities (FRO) department and has more than 25 years of experience in managing the commercialization of technologies within IT industries and has served as the CTO/CEO of multiple high-tech startups in Europe and the U.S. Prior to joining ASEE, Dr. Ivanitzki served as managing director of the Ethiopian Institute of Technology in Mekelle, Ethiopia; previously, he served as Dean of the College of Engineering and IT at DeVry University in Houston, Texas. Dr. Ivanitzki may be reached at t.ivanitzki@asee.org

RASHIDA JOHNSON has more than twelve years of experience managing government grants and contracts awarded to the American Society for Engineering Education. Ms. Johnson has expertise in contract administration, budget tracking and management, proposal development, financial reporting, monitoring, and evaluation of project goals, and the general administration of the grant lifecycle. Ms. Johnson has also been integral to developing outreach strategies for attracting the highest and most uniquely qualified postdoctoral talent. Ms. Johnson holds a master's degree in public policy from Georgetown University and Bachelor of Arts degree in Government and International Relations from Smith College. Mrs. Johnson may be reached at r.johnson@asee.org

Smart Speakers: Can They Be Trusted?

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Abstract

Smart speakers always remain in listening mode. As smart devices, they link back to servers and, with the help of smart assistants, wait for commands to begin interaction. The fact that smart speakers remain in listening mode forever means they continue to gather data about their surroundings even if no command is issued. It is possible to tell who someone is by listening to what is discussed. As such, smart speakers gather adequate information about people's lives to create a profile about them. Tech companies actively collect data about their users. At times, the government makes use of this information. Other people using the same smart speaker can also access personal information that does not belong to them. The people using smart speakers have minimal control over how their personal collected data is used and by whom. However, part of the reason smart speakers raise privacy concerns comes from the inadequate accountability by users. People use smart speakers but do not take the time to review the privacy guidelines and learn about the privacy features. In this current study, the author found indications that privacy protection tendencies were not expected. People who use smart speakers and other devices for smart homes that use the Internet of Things (IoT) frequently do not take part in social, technical, and data-linked privacy safeguard behavior. With people paying inadequate attention to privacy and how to ensure that their smart speakers do not listen to them when not activated, the question arises as to just how much these devices take in without the user's knowledge and consent.

Introduction

Fast progress has been made with the Internet of Things (IoT). IoT devices are intelligent systems constantly making their way into the daily lives of people and households. However, with such devices, people also increase their concern about what detailed and personal information is gathered and how this data is used (Guhr, Werth, Blacha & Breitner, 2020). Unfortunately, the role played by privacy is still significantly unchartered in the setting of smart homes. Smart speakers are part of IoT technologies in smart homes. Smart speakers are mobile devices that function on voice regulation using artificial intelligence and normal language processing to enable various hedonic and functional responsibilities such as reminders, playing music, and obtaining data (Lau, Zimmerman & Schaub, 2018). In most cases, the smart speaker is found in homes and buried deep in a whole smart-home network. Smart speakers are growing by the day to be mainstream. In the U.S., the adoption rates of smart speakers are high. As of December 2018, 66 million units were purchased (Feiner, 2019). Aside from the U. S., Europe also registers a noteworthy number in adopting smart speakers. In 2018, statistics indicated that smart speakers were available in 15.8 million European households (Cannizzaro, Procter, Ma & Maple, 2020). The international market for smart speakers is projected to triple by 2023.

Smart speakers operate constantly. They remain in a listening mode waiting for audio acknowledgment with a chosen phrase or word from the smart homeowner (Guhr et al., 2020). Upon hearing the word, the smart speaker then activates and starts interacting with the person. Upon activation, the transmission of live audio information using Wi-Fi to third parties for processing and storage begins (Guhr et al., 2020). The fact that smart speakers are always on results in a significant privacy risk. Research indicates that privacy protection tendencies are not common. People who use smart speakers and other devices for smart homes that use IoT frequently abstain from taking part in social, technical, and data-linked privacy safeguard behavior. There have been additional and recent discussions on privacy indifference and cynicism (Choi, Park & Jung, 2018). With people paying inadequate attention to privacy and how to ensure that their smart speakers do not violate it, the question arises as to just how much these devices store without the user's knowledge.

Research Question

On privacy matters, are smart speakers listening in without the user's knowledge?

Literature Review/Theoretical Literature Review: Social Construction of Technology Theory

Technology displays an intricate bond with social circumstances. According to Sillar (1996), technology is associated with human emotions, enabling the use of artifacts and objects. Human feelings have a significant role in the association between technology and human beings. The sociological viewpoint in innovation study examines how the social framework affects the procedure and products of an innovative effort (Yousefikhah, 2017). The sociology of technology goes beyond applying theories and the framework of the sociology of science and technology. Concerning the technology determinism perspective, the link between technology and society is that the two are distinct spheres and technical modifications take place freely in the confines of the technological domain. In this perspective, society lacks an impact; however, technology impacts society and defines the development course (Elle, Dammann, Lentsch & Hansen, 2010).

The Social Construction of Technology theory states that human events determine technology. With the construction of the technology determinism theory, there is a notion that technology shapes human events and technology due to the political, social, cultural, and economic setting (Burns, Corte & Machado, 2016). People who are in support of this concept identify as social constructivists. Social constructivists believe that technology is hard to understand without the comprehension of the social setting. This framework, in the confines of the science and technology studies sector, has links to the sociology of science. The theory reacts to the technological determinism that recognizes technology as the shaper of human events (Burns et al., 2016).

The idea of innovation is still intangible and vague. However, the term innovation can be defined from the standpoint of sociologists with the concept that points to the new organizational procedures and sequences and new services and products (Dahlin, 2014). The sociological perspective in the study of innovation focuses on how social structures affect the products as much as the process of innovative activity (Dahlin, 2014). Sociology of innovation pinpoints the characteristics of innovation and its structural configurations such as social organizations, networks, and institutions that impact innovation. There is an established link between sociology and technology and its innovations. This theory explores how social characteristics affect technology, such as smart speakers, how they develop, and how they are used to gather information.

Empirical Literature Review: Companies Listen to their Users

There are many reasons why tech corporations like Google or Facebook choose to listen to what people say to their smart devices. The tech corporations need to assess samples from the population that use their products (Molla, 2019). User conversations give these companies adequate room to capture what they need. From the conversations, the tech companies can improve upon the weak points of their products to benefit the user base. Workers from tech companies take time to listen to such conversations, taking note of keywords to arrive at informed perceptions concerning the user's needs and market trends. Nonetheless, the samples used by the tech companies from the user population maintain anonymity (Molla, 2019). There is no way of tying analyzed data back to a particular user. However, this does not offer any assurance. By listening to what someone is saying or talking about, it is possible to develop a background file on them and determine who they are. Smart speakers are private-sensitive IoT devices (Malkin, Deatrick, Tong, Wijesekera, Egelman & Wanger, 2019). Every smart home device can bring to light data concerning the habits of its owners. Nonetheless, studies indicate that people think of two types of information that count as sensitive: videos and audio recordings from home. Smart speakers work with smart assistants, which act as the brains for voice technology for Siri, Alexa, and many others (Molla, 2019). These smart assistants remain on the lookout, waiting for their wake word to act as an activation to begin recording and transmitting data to servers. After transmission to the servers, the smart assistants gauge the best way to react to whatever prompts they are issued.

There is a constant fear that people's phones continue listening in on what they say even when the owners are not speaking directly to them. Close to 43% of people who own smartphones believe that their mobile phones record what they say without their consent (Molla, 2019). Part of the notion that smart devices listen in on people without their permission comes from the content peddled by advertisers. Advertising content seems to always relate to what people think about it. Even though there is no factual proof that smart devices listen in without consent, signs are present.

Personalization of Preferences in Daily Choices

Smart speakers can personalize the owners' preferences. This personalization takes place without specific instructions from the owner of the smart speaker. Smart assistants embedded within the servers of these smart speakers take note of keywords to determine what the owners like and dislike. People in the U.S. who have smart speakers display mixed sentiments concerning the importance of smart speakers in personalizing their preferences. According to Auxier (2019), close to one in roughly five people who own smart speakers, amounting to 18%, indicate that smart speakers must consider their preferences and interests when reacting to queries and instructions. Thirty-eight percent of people who own smart speakers suggest that it is somewhat important for smart speakers to do the same (Auxier, 2019). Close to four in ten people in the U.S. who have smart speakers indicate that it is not essential for smart speakers to personalize what they want.

Many people who own smart speakers do not wish to obtain additional personalized services. Fifty-eight percent of respondents in a Pew Research Center study indicated that they did not want their smart speakers to improve their preferences and interests (Auxier, 2019). The other 42% wanted the opposite. The research added another important finding about looking for information. When people were asked whether they would agree to personalization, even if it meant that the smart speakers had to gather additional personal data, 66% of the respondents did not agree with the idea (Auxier, 2019). Smart speakers can personalize their services using the 2019 study from Pew Research Center as a pointer. However, to personalize their products and services, smart speakers take the initiative to gather additional personal data from the customers. In collecting this information, there is no guarantee that the owner's consent is sought—this lack of assurance results in a breach of privacy.

Smart speakers have a built-in automatic speech recognition (ASR) system to facilitate natural communication between the user and the device. Smart speakers are always on and constantly recording their surroundings for ease of use. The speaker should only respond to a specific trigger, hot or trigger word. However, in their research, Schönherr, Golla, Eisenhofer, Wiele, Kolossa, and Holz (2020) discovered that local and cloud ASR engines were misrecognizing many accidental triggers, with Alexa, Echo, and Amazon as the top three in trigger recognition.

User Opinion on Privacy Issues

For most people using smart devices like smart speakers, the benefits go past their privacy concerns. However, the big question is whether people using smart speakers make informed choices. Is it possible that people fail to fully comprehend the consequences and regulations at their disposal? Users might not even know that their interactions go into a forever storage system controlled by the manufacturers of the smart speakers (Lutz & Newlands, 2021). Other people in the smart home can review personal interactions when they wish. Privacy is compromised and the people involved are unaware of it. In another study by Malkin et al. (2019), it is clear that people have no idea that their interactions go into permanent storage. People are also unaware of the possibility of assessing their past interactions by retrieving stored information. Unsurprisingly, some people feel the data stored with voice assistants in smart speakers do not count as sensitive. However, people are dissatisfied with the prevailing retention guidelines. Overall, people disagree with the permanent storage of their information by smart assistants in smart speakers (Malkin et al., 2019). Many people also find it unacceptable to review their information and interactions with smart assistants and manufacturers of smart speakers. Very few people agree that they employ the provided privacy characteristics of these smart speakers (Malkin et al., 2019). People should take up proposals for privacy features like the automated deletion of recordings. All these findings and claims prove that people lack complete information on the behaviors of their smart speakers and the available privacy features.

In another report by the Pew Research Center (Auxier et al., 2019), there is conflicting information regarding people's knowledge of the privacy concerns for their smart speakers. Many people in the U.S. believe that their online actions are regularly tracked and assessed by tech corporations. Six out of ten people believe that it is impossible to go through a typical day without some information about them being collected by smart devices for the benefit of the U.S. government or the involved tech companies (Auxier, Rainie, Anderson, Perrin, Kumar & Turner, 2019). Many people in the U.S. (79%) also register concern over how their information is used by these tech companies (Auxier et al., 2019). People indicate that they do not have adequate authority over how the government and tech companies use their data.

Americans' regard for digital privacy covers people who gather, store, and use personal data. In addition, a significant percentage of the public lacks confidence in companies being good stewards of the information collected (Auxier et al., 2019). Seventy-nine percent of people in the U.S. are not confident that tech companies will agree to make mistakes concerning the misuse and compromise of personal data available to the public. Sixty-nine percent are not satisfied that companies will not use their data in ways that bring discomfort (Auxier et al., 2019). Despite the American public harboring concern over several aspects of their digital privacy, the majority admit they lack diligence in attending to privacy guidelines and terms of services with products they use daily (Auxier et al., 2019). Even though 97% of the American public agrees to be sought for consent on approval of privacy policies, close to only one out of five adults agrees that they go through privacy policies before deciding to do the same (Auxier et al., 2019). Thirty-eight percent agree that they read the policies before agreeing to the same, with 36% saying they never read before agreeing.

In essence, part of the problem with privacy regarding smart speakers stems from the fact that users are unaware of the privacy guidelines. People do not engage in learning about privacy and how they can safeguard themselves. Even though companies manufacturing smart speakers might have additional privacy features, not all people use these features. Part of the privacy issues arising from smart speakers listening in on owners come from ignorance and reluctance to fully comprehend device features and capabilities.

Discussion

Smart speakers continue to be adopted by more households, becoming a mainstream technological invention. Smart speakers operate continuously, meaning they do not turn off unless there is an error with the Wi-Fi and network connection. These smart devices maintain a listening mode awaiting audio recognition with a designated word from the owner. According to research, privacy safeguard behaviors are not regular for people using smart devices such as smart speakers (Guhr et al., 2020). People using smart speakers like Alexa and Siri refrain from engaging in technical, social, and data-associated privacy protection behaviors. Part of the blame falls on the oblivious nature of the users.

The Social Construction of Technology theory explains how society interacts with technology. According to the theory, human actions determine technology's course (Youseffikhah, 2017). Social features impact the technology of smart speakers in determining their development, improvement, and how they collect information about their users. The theory can also be used to understand why tech companies providing smart speaker services and products choose to listen in on their customers. These tech companies need to evaluate population samples concerning the use of their products.

Smart speakers can personalize people's preferences, but most people using smart speakers do not choose to personalize their experience. To customize preferences, smart speakers take in personal data, which can be acquired without consent from the user. In the long run, privacy is breached. People do not have complete control over the information gathered and stored by their smart speakers (Auxier, 2019). The government and tech companies can access and use this information. Other people with access to smart speakers can review personal data that does not belong to them. With the use of smart speakers, there are many ways privacy is compromised, and users are not even aware. Even though people express worry over different perspectives of digital privacy, many agree that they do not have the diligence to read privacy guidelines and terms of service on products. A significant part of the challenge in using smart speakers is that privacy is compromised because users do not know about privacy features and guidelines, and even those who do know about them do not take the initiative to use them.

Conclusions and Recommendations

Smart speakers always remain in listening mode. As smart devices, they link back to servers and, with the help of smart assistants, wait for commands to begin interaction. The fact that smart speakers forever remain in listening mode means they continue to gather data about their surroundings even if a command is not issued. It is possible to identify a person by listening to their conversations. As such, smart speakers gather adequate information about people's lives to create a profile. Tech companies actively collect data about their users. At times, the government makes use of this information. Other people using the same smart speakers can also access personal information that does not belong to them. The people using smart speakers have minimal control over who collects their data and how it is used. However, part of the reason smart speakers raise privacy concerns comes from the inadequate accountability by users. People use smart speakers but do not take the time to review the privacy guidelines and learn about the privacy features.

Few countermeasures can be used to address the privacy concerns of smart speakers. Users of smart speakers rely on the voice channel for communication, which creates a vulnerability. Using biometrics to identify the device owners is a valid defense against such weakness in smart speakers. Another approach is to allow the users to customize their own wake words. For example, users can repeat the wake word, saying, "Alexa, Alexa, Alexa." Future research is needed to help find more countermeasures to safeguard the privacy concerns of smart speaker users.

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Biography

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