A Workshop for Integration of Internet of Things into Green Energy Manufacturing

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Abstract

This paper describes enhancement of green energy manufacturing subjects using a project based learning workshop with Internet of things (IoT). The Internet of things is a collection of all physical devices that are controlled or monitored over the Internet. The evolution of IoT has led to the diffusion of wireless personal devices, such as smart mobile phones, personal computers and wearable devices, designed to operate over the Internet. It is a growing area in the field of engineering and is aimed at reducing human effort. While the IoT may have tremendous applications in engineering, its potential in the field of green energy manufacturing is often neglected. In this workshop we aimed to spread awareness about the uses and possible contributions of Internet based devices in clean energy and energy efficiency. The workshop was designed to provide students with a firm grounding in the principles of sustainable manufacturing environment and real-world energy efficiency improvements on general systems. Our training materials were designed for various students in engineering so that they become interested in green energy manufacturing. This workshop allowed the students to explore the possibilities of the application of the Internet of things to areas beyond green energy and inspire them to create sustainable manufacturing for a better future. The paper presents an educational strategy to integrate IoT into green energy manufacturing and to cultivate leaders in the field among minority and female engineering students. Successful completion of the projects in the workshop has led to excellence in green energy and advanced engineering education.

Keywords: Workshop, green energy manufacturing, internet of things, engineering education

INTRODUCTION & BACKGROUND

This paper outlines the results of the workshop "The Internet of Things – Integration with Green Energy Manufacturing." The workshop was initiated and jointly organized by the Industrial, Manufacturing and Systems Engineering (IMSE) Day at the University of Texas El Paso in April 2016. This paper is not confined to summarizing the discussions and conclusions of the workshop, but also elaborates on themes identified at the workshop to substantiate what the Internet of Things might become in the future. The semantic origin of the expression is composed by two words and concepts: "Internet" and "Thing", where "Internet" can be defined as "The world-wide network of interconnected computer networks, based on a standard communication protocol, the Internet suite (TCP/IP)", while "Thing" is "an object not precisely identifiable" Therefore, semantically, "Internet of Things" means "a world-wide network of interconnected objects uniquely addressable, based on standard communication protocols". The Internet of Things (IoT) refers to the use of intelligently connected devices and systems to leverage data gathered by embedded sensors and actuators in machines and other physical objects. For consumers, the IoT has the potential to deliver solutions that dramatically improve energy efficiency, security, health, education and many other aspects of daily life. For enterprises, IoT can underpin solutions that improve decision-making and productivity in manufacturing, retail, agriculture and other sectors[1-2].

Green Manufacturing is defined as "a system that integrates product and process design issues with issues of manufacturing planning and control in such a manner as to identify, quantify, assess, and manage the flow of environmental waste with the goal of reducing and ultimately minimizing environmental impact while also trying to maximize resource efficiency". Increased environmental consciousness among manufacturing industries helped to foster new techniques for streamlining processes and increased reusability. Connecting manufacturing devices and aggregating the data created is enabling manufacturers to reduce overhead, conserve resources, increase profits and optimize operational efficiencies. There are many ways the IoT helps in optimizing manufacturing: inventory control and supply chain management help companies become more efficient. But one of the greatest advancements made possible by the IoT is energy management. Energy is often one of the largest expenses for manufacturers; and, unfortunately, it is also one of the most ambiguous[4-5].

Increased global adoption of green energy and green manufacturing technologies presents a reformation of engineering education geared toward renewable energy and green manufacturing practices. According to a research brief titled "Investment in renewable energy generates jobs. Supply of skilled workforce needs to catch up" from the digest "Skills and Occupational needs in Renewable Energy[6-9], it is estimated that by 2030 up to 12 million people could be employed in clean energy sectors. It is also mentioned that, there is a widespread skill shortage of engineers and technicians with knowledge in in the field of renewable energy technologies. Based upon the need for increased skills in renewable energy and green manufacturing technologies, this paper discusses a project based learning approach taken, along with a series of workshops held in the field of Green Energy Manufacturing to enhance student professional success. In the following sections of this paper, a detailed explanation of the project used for project based learning as a part of green energy manufacturing class and green energy manufacturing workshop series are given.

WORKSHOP GOALS AND AIMS

The workshop on four topics was conducted by Drexel University to support and expose minority-engineering students towards cultivating their skills in emerging green energy manufacturing technologies. The workshop was organized and coordinated as a part of Sixth Annual 2016 Industrial, Manufacturing, and Systems Engineering (IMSE) Day held at the campus of the University of Texas El Paso during the days of the 21st and 22nd of April. This workshop explored how the IoT not only connects physical and digital spaces, but how these networked spaces and objects might become playfully responsive characters that engage people and interact with the built environment in new ways. We seek to address the issues surrounding the integration of emerging technologies with the highly varied assemblies of intelligent or smart city that perhaps exist already within these spaces or will be deployed in them in the near future. The key components of emerging technologies are found in a variety of loosely-related current research areas in IoT geared towards green manufacturing and energy efficiency. The details of the workshop is given below.

Workshop topic 1: Green logistics (Environmentally responsible logistics)

This workshop assignment aims to introduce logisticians to green logistics and encourage them to think in "green" terms, to highlight the challenges and to indicate some advantages of thinking "green." Organizations have to face changing circumstances for several years. In addition to increasing diversity and dynamics, environmental issues become more important. Social, political and economic demands for sustainable development force organizations to reduce the impact on the environment of their supply chains and to develop sustainable transport and supply chain strategies. There are strong interactions between logistics, environment and natural resources. In addition, the approach of logistics is interdisciplinary, holistic and cross-company. Realizing environmental objectives can be done in synergy with other strategic and financial goals. This is the basis of the great potential of this new logistics problem and challenge. The main objective of logistics is to co-ordinate these activities in a way that meets customer requirements at minimum cost. In the past this cost has been defined in purely monetary terms. As concern for the environment rises, companies must take more account of the external costs of logistics associated mainly with climate change, air pollution, noise, vibration and accidents. This project is examining ways of reducing these externalities and achieving a more sustainable balance between economic, environmental and social objectives.

Logistics and Reverse Logistics

While Logistics is defined as "Process of planning, implementing and controlling the efficient, cost-effective flow of raw materials, in process inventory, finished goods and related information from the point of origin to the point of consumption for the purpose of conforming to customer requirements," Reverse Logistics implies "that to the point of origin for the purpose of recapturing value or proper disposal." Logistics is the integrated management of all the activities required to move products through the supply chain. For a typical product this supply chain extends from a raw material source through the production and distribution system to the point of consumption and the associated reverse logistics. As shown in figure 1, the logistical activities comprise freight transport, storage, inventory management, materials handling and all the related information processing. Green (environmentally responsible) logistics means improving operational efficiency by conserving resources and reusing them as much as possible. Benefits of Green Logistics includes, 1. Improves operations by employing an environmental solution, 2. Improves Agility: Green supply chain management help mitigate risks and speed innovations, 3. Increase Adaptability: Green supply chain analysis often lead to innovation processes and continuous improvements, and 4. Promotes alignment involves negotiation policies with suppliers and customers which results in better alignment of business processes and principles.

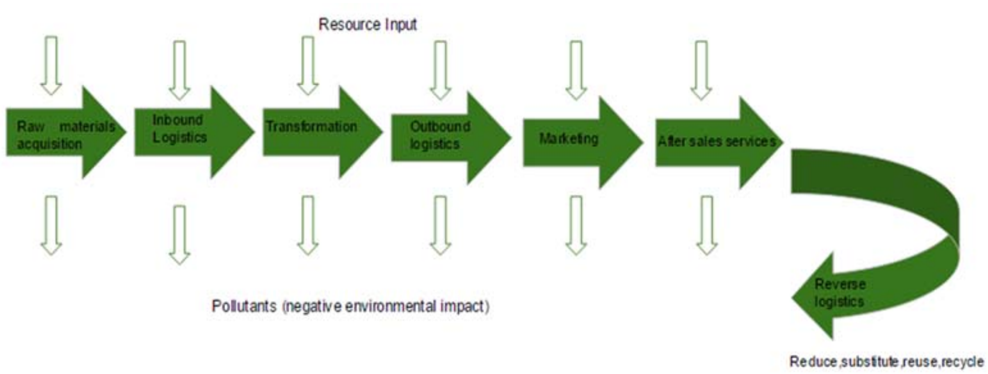

Figure 1: Flow of Green Logistics

Logistics and transport activities have been identified as having a major impact on the environment in which we all live. Consequently logistics and transport have attracted significant legislation at both national and international level. Targets for improving environmental performance have been set by the international community via the Rio, Kyoto and the Copenhagen summit meetings. The International Organization of Standards (ISO) 14000 series of standards provides a formal system for the management of environmental matters. The ISO 14000 family addresses various aspects of environmental management. The very first two standards deal with environmental management systems (EMS), including ISO 14001:2004 provides the requirements for an EMS and ISO 14004:2004 gives general EMS guidelines. The other standards and guidelines in the family address specific environmental aspects, including: labelling, performance evaluation, life cycle analysis, and communication and auditing.

This workshop provides a framework for managing environmental issues rather than establishing performance requirements. It is seen as a process that starts with the creation of an environmental policy and leads on to: planning how legal obligations and targets will be met; implementation (including operational controls) and operation of the plan; training and communicating with staff; and control of relevant documentation. The technologies in Logistics includes_RFID, WiFi IEEE 802.11, Barcode and QR Code, ZigBee IEEE 802.15.4, and smartphones. The advantages of this method includes low-cost and user-friendly. In the workshop, we demonstrated how the use of cell-phone-Apps combining with both barcodes and QR codes allows the consumer to connect to the IoT with the simple scan of a smartphone or tablet, including width-modulated and height-modulated barcodes. Participants in the workshop learned two dimensional barcodes for green logistics applications. There are two basic types of 2-D bar code symbols as shown in figure 2: 1. Stacked bar codes: Consists of multiple rows of conventional barcodes stacked on top of each other, and 2. Matrix symbolizes; Consists of 2-D patterns of data cells that are usually square and are colored dark or white.

(a) (b)

Figure 2: (a) 2-D stacked bar code and (b) 2-D Matrix barcode (Data Matrix)

QR code is a two-dimensional barcode defined by the industrial standard ISO/IEC18004:2006, developed and protected by the Japanese company Denso Wave Incorporated, which is a member of Toyota group. Each QR code is structured by dark (logical ''1'') and light (logical ''0'') modules. The modules additional data from the database if needed, which the producers provided for each product, but are not printed in the QR code. If the processing of the food product includes various ingredients, the unique ID of the new product is also connected to the ID of all the ingredients, which enables later traceability of products. This way, there is a database which contains all the data on the product, from its origin, and origins of all of its ingredients, through all processing stages and transport.

In the environmental impact evaluation system, QR codes are used for tracking and tracing soda products in the major part of food chain in processing, distribution and retail, since the costs of using the QR codes are low and they do not incur additional value to the price of a single product.

Using QR codes on the food product packaging for transferring key product data should provide minimal readability conditions, which would allow the consumer to easily reach the data contained in the code. This is essential, as the whole system model has no significance if the reading of a QR code adds delay time to existing processes that are performed on the product. In order to get a clearer image of readability of QR codes of various sizes by mobile phones, cell phones of various producers running the Android and iPhone operating system, with different procedures, were used.

(a) Plastic bottle (b) Glass bottle (c) Aluminum can

Figure 3: Beverage container types including (a) Plastic bottle, (b) Glass bottle, and (c) Aluminum Can.

A list of used beverage containers is given in figure 3. A case study was demonstrated in the workshop: Which beverage container (aluminum can, plastic bottle, and glass bottle) has the lowest environmental impact? This QR code gives information about the origin of raw ingredients of the product to the consumer, and thus facilitates the decision process for buying a particular product, which is no longer connected only to the specific brand, but also to particular suppliers of raw ingredients. The consumer can read the following data contained in the QR code on the product via a smartphone: ID code of the product, factory designation, date and time of production, quality class, etc. After these time measurements, the readability testing was performed for QR codes applied to objects with curves.

Table 1: Environmental impact indicator: Primary energy requirements

Beverage container	Material production	Container manufacturing	Use & distribution 1)	Container recycling 2)	Total energy
Aluminum	8.5	0.4	0.1	-3.6	5.4
PET	3.6	0.7	0.1	-0.3	4.1
Glass	5.3	1.3	0.5	-0.5	6.6

Table 1 shows the total energy for decoding the contents of QR codes. The read times are given for all the beverage container types used in the research. The total energy were calculated only from the data for the phone models that could read the given QR code. By the analysis of the data, it can be concluded that the read times for QR codes are not influenced by the beverage container type, but rather the hardware of the phone model that performs the decoding of the data from the image of the code. After the testing of QR code readability on various beverage container types, the readability of QR codes was tested on objects with curves. These measurements were conducted in order to test the total energy due to beverage container types. This workshop presented the results on a QR code readability analysis on various soda types with product packaging. Reading of QR codes was performed with newer generation smartphones running the Android or iPhone operating system. Products create environmental impacts at all stages of their life cycles. It is important to consider the entire lifecycle of products.

Workshop topic 2: Arduino-based Internet of Things for Environmental Monitoring

The workshop showed students how to use Arduino to create gadgets for measuring air quality. Air quality monitoring is extremely important in today's world, especially in a working environment as it has a direct impact on people present. Air pollution is on the rise due to a number of anthropogenic activities and its monitoring is of vital importance to mitigate certain measure to control it. Here we put forward a low cost and low power sensor based system for air quality monitoring. This sensor based system in contrast to traditional stationary air quality monitoring stations is small and portable based on a low cost sensors and microcontrollers that can be commercially used by number of people. The data from the sensors on Arduino system can be collected from various places and be stored, plotted graphically and easily updated. Vital to the success of sensing applications is the high quality data from the sensors of the system. The aim of the experiment is to create an Arduino based greenhouse gas emissions monitoring device that logs real time data on to a remote server.

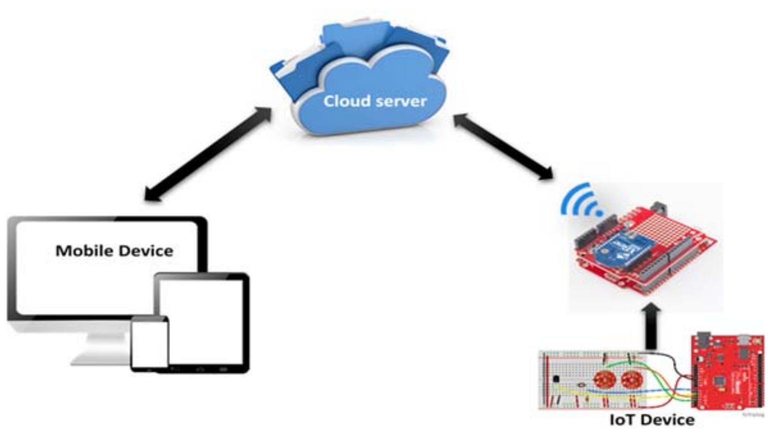

Figure 4: System layout

Air quality is a major concern in modern cities and in developing countries nowadays. As an instance, carbon monoxide is highly toxic to humans as it can cause severe headaches, asphyxiation due to formation of carboxyhemoglobin and even death if exposed for prolonged time. Also these pollutants are responsible for many environmental problems such as acid rain and ozone layer depletion. Hence, air quality monitoring is vital nowadays especially in the urban and industrial areas.

Air quality monitoring by monitoring stations. Nowadays, air pollution is monitored by static air quality measurement stations that are operated by official authorities. These stations are highly reliable and can measure the pollutants in air to a high level of accuracy and precision using analytical instruments, such as mass spectrometers. However, extensive cost of acquiring and operating such stations limits the number of installations. Air quality monitoring by Arduino. The concentration of air pollutants such as CO, Methane, etc. is highly location-dependent. The urban areas with heavy traffic concentration and industrial areas have a considerable impact on the local air pollution. Since the air pollution monitoring stations are costly and so are limited in number. With the help of Arduino based system which is a small and portable measurement system which can be equipped with various gas sensors (such as CO, CO_2, NO_2, O_3, etc.) and microcontroller that can be used by a number of people. Thus system like this can provide the user with: • Low-cost and low-power measurement hardware that is suitable for mobile measurement; • User-friendly data collection and processing software; • Gathering high quality data; • Easy to use instrument that can be used commercially by a large number of people. Connecting a small-sized, low-cost CO sensor to an Arduino microcontroller module which is then connected to a computer via serial communication. The data collected by the Arduino microcontroller from the sensor is then sent to the computer software where it gets recorded and plotted in real-time.

System Design

The workshop presented the required materials for the system design, including: Arduino Microcontroller, X-Bee Wi-Fi Module, X-Bee Shield, Temperature Sensor, Photocell (Light Sensor), Methane CNG Gas Sensor, Carbon Monoxide Sensor, Gas Breakout Boards, Bread Board, Jumper Cables, and 10kΩ-22kΩ resistors. The Flowchart of the system is shown below in figure 4. Here, we have an Arduino system that includes the necessary analog sensors connected to X-bee Wi-Fi module. To stream the data on a server, we create an API with public and private keys to access the data being streamed. The data stored can be accessed by any device including a computer or a mobile device.

Implementation

The system here uses a X-bee Wi-Fi module, shield and the Arduino as shown in figure 5 below. Using a collection of analog sensors to monitor carbon monoxide, methane, temperature and the light condition in the rom being tested. Connection for the system is shown in figure 6.

Figure 5: X-bee Wi-Fi module

Table 2: Sensors connecting Arduino pins

Sensor	Arduino Pin	Notes
Photo resistor (Light)	A0	Connect a 10kΩ resistor from output to ground. Tie other leg of photocell to 5V
TMP36 (Temperature)	A1	Power the TMP36 off the 5V rail. The temperature (in °C) is the (read voltage - 0.5V)*100
MQ-4 (Methane)	A2	Connect a 22kΩ resistor from output to ground. These things suck a lot of power, adding a cap nearby may help to smooth out the voltage supply
MQ-7 (Carbon-Monoxide)	A3	Connect a 10kΩ resistor from output to ground. These things suck a lot of power, adding a cap nearby may help to smooth out the voltage supply

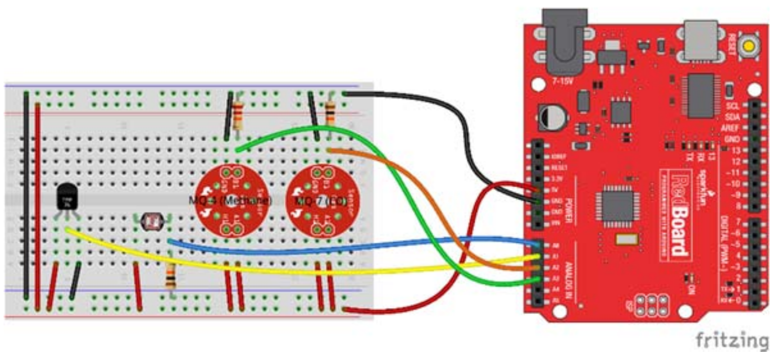

Figure 6. Pin Connection

Table 2 and the diagram in figure 6 show the connection of the sensors to the Arduino system. The sensors used are as follows: 1) Photo resistor: - A photo resistor (or light-dependent resistor, LDR, or photocell) is a light-controlled variable resistor. The resistance of a photo resistor decreases with increasing incident light intensity; in other words, it exhibits photoconductivity. A photo resistor can be applied in light-sensitive detector circuits, and light- and dark-activated switching circuits. 2) TMP36:- The TMP36 is a low voltage, precision centigrade temperature sensor. It provides a voltage output that is linearly proportional to the Celsius temperature. It also doesn't require any external calibration to provide typical accuracies of ±1°C at +25°C and ±2° Cover the −40°C to +125°C temperature range. We like it because it's so easy to use: Just give the device a ground and 2.7 to 5.5 VDC and read the voltage on the Vout pin. The output voltage can be converted to temperature easily using the scale factor of 10 mV/°C. 3) MQ-4:- his is a simple-to-use compressed natural gas (CNG) sensor, suitable for sensing natural gas (composed of mostly Methane [CH_4]) concentrations in the air. The MQ-4 can detect natural gas concentrations anywhere from 200 to 10,000ppm.

Data Stream

Setting up a data stream. There are a lot of services on the internet that let you stream data onto their servers. For this workshop, we will be using Sparkfun's data stream which is a free service and a great place to start. To begin, head over to data.sparkfun.com and click Create. Fill in the blanks with student feed's title and description. (Then take extra care to fill in the Fields textbox. This comma-separated list of words defines how students interact with the data stream to post a list of unique values). Students can make their fields as descriptive and short as students can. They used "methane", "co", "temp" and "light" to describe the readings.

After students created their feed they will be led to the stream's key page. Copy down all of the information on this page. As with the help these specific set of keys, they will can access the data that is being streamed form your system. Students can see some set of keys named public, private and delete. The public key mentioned above is used to access the stream link for the data students are acquiring through the Arduino system. As it can be seen in the Public URL, which is a link that uses the public key. On the other hand, Private key is used to edit the stream setting you initially entered and must be kept a secret or anyone can edit your data characteristic. The delete key used to delete the URL you created using the public key.

Arduino Program

The program is written using the accompanying Arduino IDE (Integrated Development Environment) software as shown in figure 7. A basic Arduino program, or sketch can be seen above and consists of two main parts: the setup () function and the loop () function. The setup () function us called once when the program starts and is used to initialize all the variables, pin modes and libraries. The loop () function is used to actively control the microcontroller and loops consecutively.

Figure 7: Arduino Code snippet

Before students get on with uploading that code to your Arduino, there are a few variable constants students will need to modify such as the Wi-Fi name and password (if applicable) Once students have made those adjustments, students can safely upload the code. After students have sent the sketch to their Arduino, open up the Serial Monitor to get an idea of what’s going on. If their X-Bee is not connected to a network, it may take a few moments to get the handshakes and DHCP arranged with the router. Once the X-Bee is connected, students will attempt to post their first log of data. Students should see a “Sending Update”... message, followed quickly by SUCCESS! If students get a success message, they need to go refresh their public stream URL! If your message fails to log, an error message will be printed – in that case double-check that everything is defined correctly.

Using the Data. Once students have the data stream running, students have a few tools to view and manipulate the data. Students can download it as either a CSV or JSON file, by clicking the links at the top of the page. Then students can import those files into a spreadsheet or one of many online plotting services which students can use to generate graphs. The Arduino system discussed above is a small, portable and low-cost air quality monitoring system. This system can be used easily at a large scale and domestically by a large number of people. Here, the system was used to monitor Carbon Monoxide, Methane, temperature and Light concentration in an area and collected the data for the same. This sensor based system can also be used for various other gases such as SO2, NO2, CO2, O3, etc. using different sensors. This system can thus be utilized effectively by the general public for monitoring the quality of air around them.

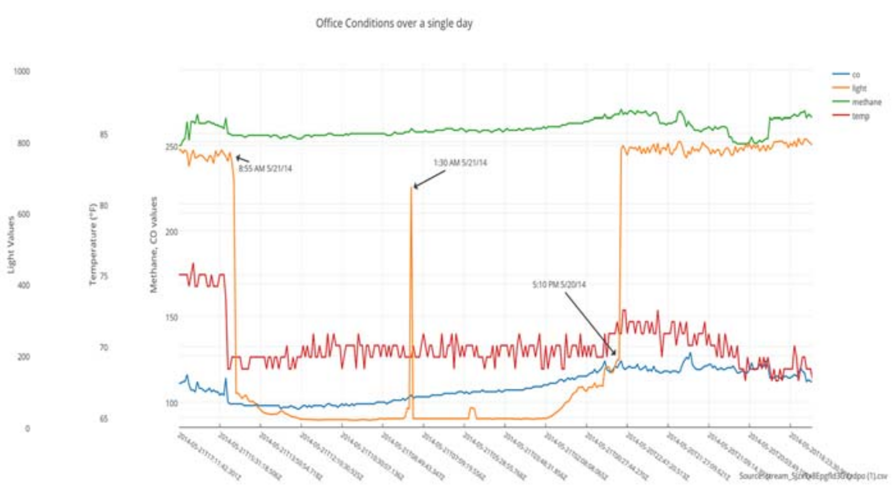

Figure 8: Collecting and analyzing data

Workshop topic 3: Energy Efficient Lighting Technology using IoT sensors

This workshop introduced participants to the energy efficient lighting technology using IoT sensors. The participants were led to a comprehensive approach to sustainable manufacturing that will also prepare them for a leadership role in sustainable manufacturing and environmental stewardship. The internet of things provides a vast array of methods for data collection, storage, and access for data analysis. The consumer need for instant data gathering through readily available portable devices has become the common goal within manufacturing. Research and development to reduce material waste, while maintaining high accuracy and precision, has been the theme of 21st century technology. Mobile devices have improved dramatically since the early

2000s. Connectivity can either be established through Bluetooth, infrared, or network communication with many mobile devices.

Portable devices have advanced in simplicity of use and accessibility to consumers. The workshop was to display the use of such devices for the performed experiment to take instant measurements. The recorded measurements were then to be stored through an online server, which could be accessed through an internet server. The students were given instructions to download a few available applications after becoming informed of the variety that existed on the market. The available applications were either free or charged a nominal fee below $5. Students were showed that the many free options available were enough to perform the experiment. The broad market for applications for smart mobile devices utilizes the sensors within the user's mobile device to take measurements. The application market can be accessed through the provider's marketplace. Through a search engine, the students were asked to search for light meters within the marketplace and install them into their mobile devices. The process and various applications available with different capabilities can be seen in Figures 9-11.

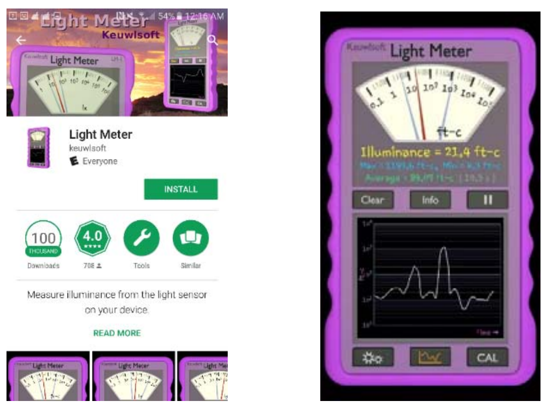

Figure 9: The application within the market place (left) and the installed application (right)

Figure 10: The installed application displays stored data (left) and the application displays graphing options and units (right)

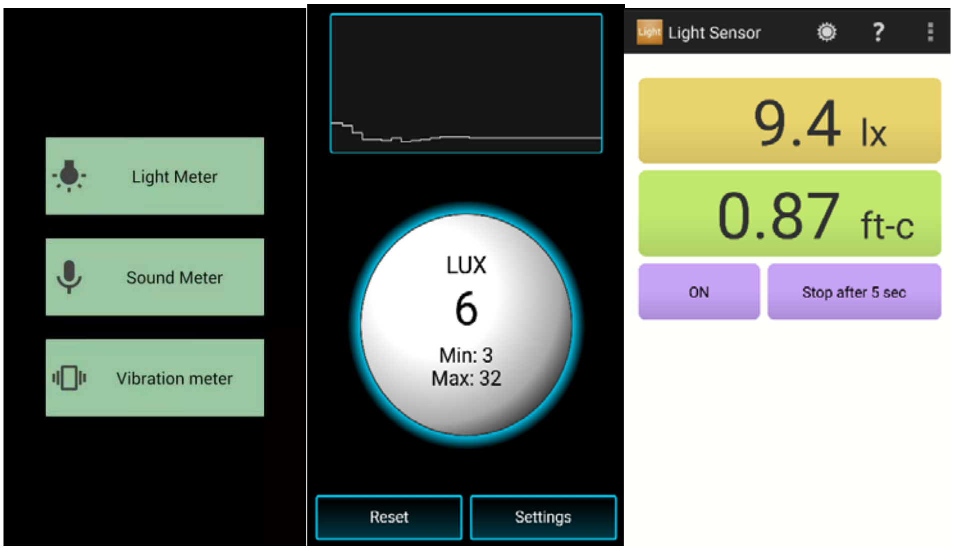

Figure 11: The image displays an application with multiple functional sensors as options (left). The image displays a basic light reading (center). The image displays units recorded after a certain amount of time (right)

Table 3: Lighting Energy Efficiency

	Incandescent	Fluorescent	L.E.D
Initial Wattage (W)	100	14	9
Initial Lumens (Lumen)	1690	800	800
Measured Lumens (Lumen)	1200	650	650
Distance from bulb base (m)	1	1	1
Measured Wattage (W)	95.5	12.7	8
Measured Current (A)	0.83	0.19	0.15
Initial Voltage (V)	120	120	120
Measured Voltage (V)	114	116	114
Calculated watt output (W)	73.68 W	39.91W	39.91
Efficiency (%)	77% (73.68/95.5)	307.8% (39.91/12.7)	498.9% (39.91/8)
Theoretical efficiency (%)	96.37068018	28.50162866	18.32248
CO2 Emission (per Day) (lb.)	1.11	0.47	0.01
CO2 Emission (per Month) (lb.)	33.4	14.1	.31

The experiment was to determine the most cost effective and energy efficient light bulb to use within industry. The students were to evaluate the lumen to watt ratio and determine the best solution to implement with regards to Facility Standards for the Public Buildings Service. Open or closed offices, conference rooms, training rooms, corridors, stairwells, storage rooms, electrical rooms, mechanical rooms, dining areas, and restrooms are classified into a system performance unit lighting power allowance for common areas (Administration, General Services, 2016). Specific luminosity is also required for the Department of Defense under the United Facilities Criteria (UFC). Table 3 displays an example of the recorded results. It should be noted that some applications stored data directly into a table and could be accessed from another device through a login ID and Password.

Lux meters can be purchased online for a minimum cost of $10. Kilowatt meters can be purchased for $50 to perform the experiment. Alternatives for this meter do exist with less available options. The expense can be spared as the technology exists within mobile devices. A global warming potential was done to display the output of each bulb during manufacturing and during use. This enabled students to understand the complexity of each manufacturing process with each given light bulb. The students were expected to understand and environmental impact of each light bulb while integrating an instant system from the internet to store and read data within the field.

Workshop topic 4: Green Energy Management: Efficiency of Heat Exchangers

During the past year, we developed several activities related to promote learning in Green Energy Manufacturing area. The laboratory modules was redesigned in "Thermodynamics and Heat Transfer Analysis" course to emphasize the Energy Conversion analysis aspects through learning-by-doing approach.

The global context regarding energy and sustainability evolved rapidly and what we considered to be emerging technologies less than a decade ago became mature technologies nowadays, already implemented at large scales in industry. Moreover, the constant preoccupation regarding green energy manufacturing as a method of reducing the carbon footprint generated not only the path towards new technologies but also to new educational programs and trends. Following these trends and industry demands, the engineering curricula evolved to include more and more courses in the area of energy conversion, green energy and sustainability. However, several "traditional" courses remained more or less the same, mostly in the area of thermal-fluid areas. While there have been reported several attempts to improve these courses by including project-based learning activities, it was concluded that such projects involving industry-like scenarios where lengthy and costly, and eventually were stopped or replaced with traditional lectures. Nonetheless, these studies and attempts had a significant contribution in underlying the importance of practical approaches in conveying knowledge to students in heat transfer and thermodynamics courses, which traditionally are dry-lecture based. Moreover, the contribution of thermal-fluids energy systems performance in global sustainable development is substantial but was not emphasized until recently. Therefore it may not be reflected in the already developed learning modules for these traditional courses.

Our team re-developed our thermal-fluid related courses in Engineering Technology curricula by including several modules involving industry-like scenarios as laboratory activities performed remotely (through Internet), using four heat exchanger configurations and thermography (using a thermal imaging camera) in teaching fundamental principles and notions of heat transfer as well as teaching more complex aspects of heat exchanger design and performance. The scenarios were inspired from manufacturing industry related energy management applications, focusing on giving the students a more global and interdisciplinary understanding of the applications of the imparted knowledge. This lab-lecture integrated approach, with ”in-lecture” Internet based remotely performed activities, complemented by hands-on laboratory activities, significantly improved the understanding, knowledge retention and also it enhanced student motivation. Students were required to compare results obtained through various methods including thermography to discuss and assess system efficiency and design parameters. We developed an Internet-based remote platform conceived for the study of the thermal energy conversion systems, as well as monitoring using virtual instrumentation. This platform will provide students with enhanced tools of study.

As traditional learning methods are time consuming and sometimes impractical, learning through the Internet will significantly increase the access to modern learning tools for all students including minorities and disadvantaged student communities, due to its affordability and ease of use, without curtailing the quality of knowledge conveyed. In recent years due to the Internet advances, the use of virtual and remote distance experiments in engineering education has been well accepted in many different education areas and at many universities.

The workshop contained a remote control accessed desktop through software known as TeamViewer. TeamViewer is a free readily available software that that can be downloaded at TeamViewer.com. The software can be accessed through either any mobile device or desktop computer. The software downloads a client host for the devices to be used, which can be shown in Figures 12 and 13. TeamViewer provides encryption for security to remote users.

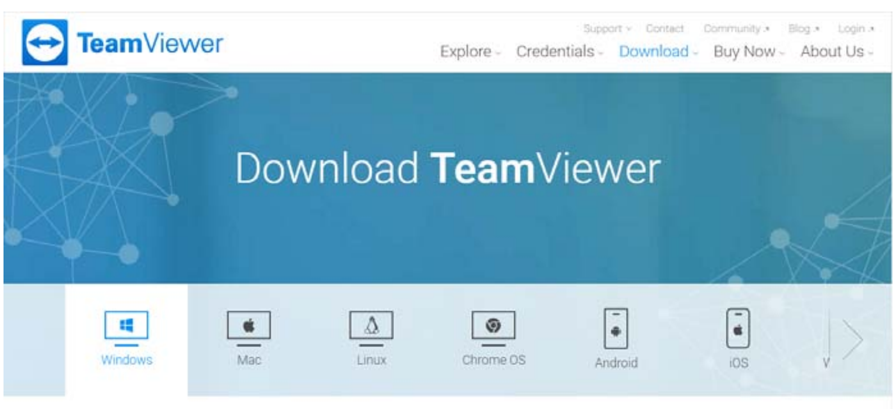

Figure 12: TeamViewer website download

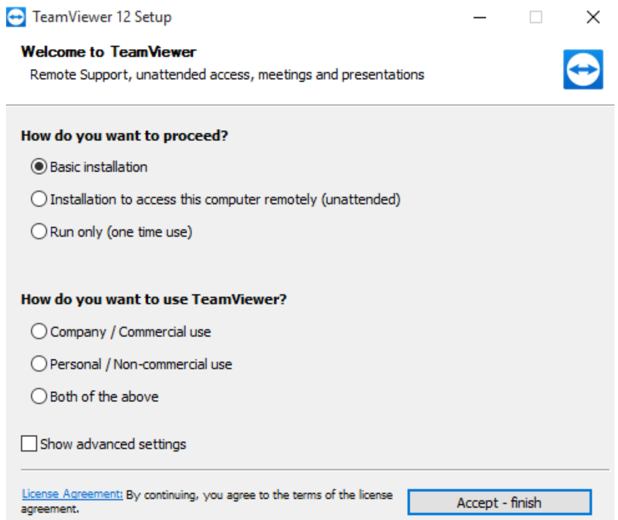

Figure 13: TeamViewer installer

The computer is then given an ID and passcode. There are additional options for the type of access the user would like to establish for the device. The user is also given the option of accessing the computer while unattended. Figure 14 displays the process of and options the user is given to the type of access needed. Once connection is established, the user has complete control over the remote computer through an internet connection. Other systems of remote access do exist, but most exist at either a monthly cost or run a limited commercial trial period.

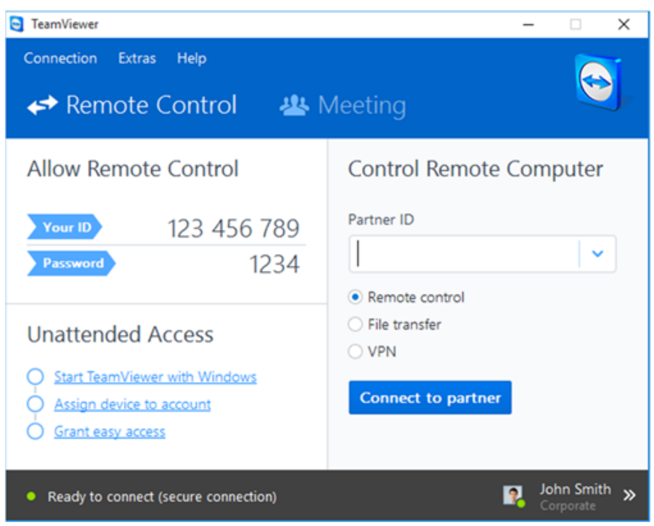

Figure 14: Displays user ID and password for remote login

The workshop provided a live feed and experiment using a heat exchanger. The Armfield heat exchanger was connected to a remote laptop with TeamViewer enabled at Drexel University. The connection to the internal microcontroller was established via USB as shown in Figure 15. The experiment was to establish a connection with an unattended system for data analysis during the workshop in Texas from Philadelphia.

Figure 15: USB connection to heat exchanger

The system used can be seen in Figure 16. The system contained thermocouples that provided a live reading as the user controlled the module through remote access. Any changes made to the system were instantaneously done. Water was needed to run the system and was manually done in advance for flow to occur. Students were then given out handouts to answer additional questions and record data from the live feed.

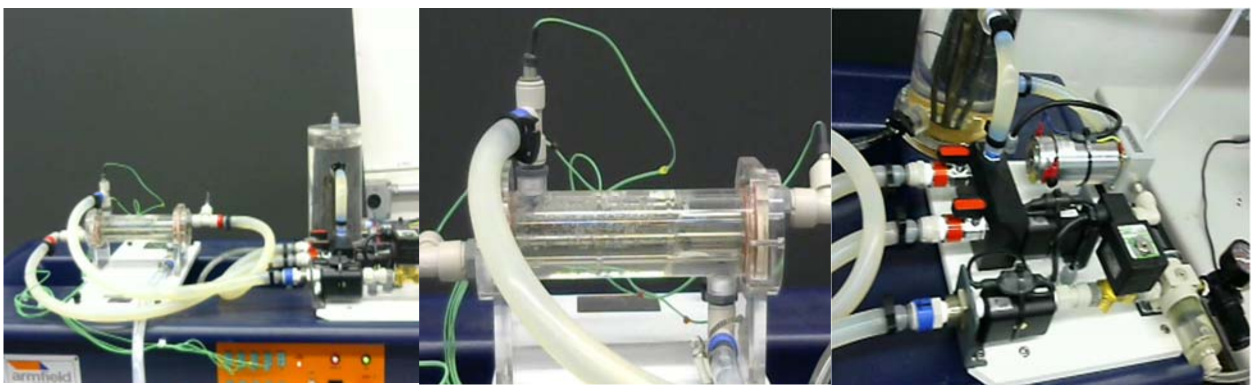

Figure 16: Heat exchanger with thermocouples

The system setup also included a thermal camera to display accuracy of results from thermocouples within the system. The students were able to visually determine the given cursers on the display and compare the temperature readings to the respective thermocouples. Figure 17 displays the desktop view through remote access that was shown in real time. The four thermocouples are displayed clearly through specific cursor points through the FLIR thermal camera software. The live data was displayed directly below the system control and thermos image.

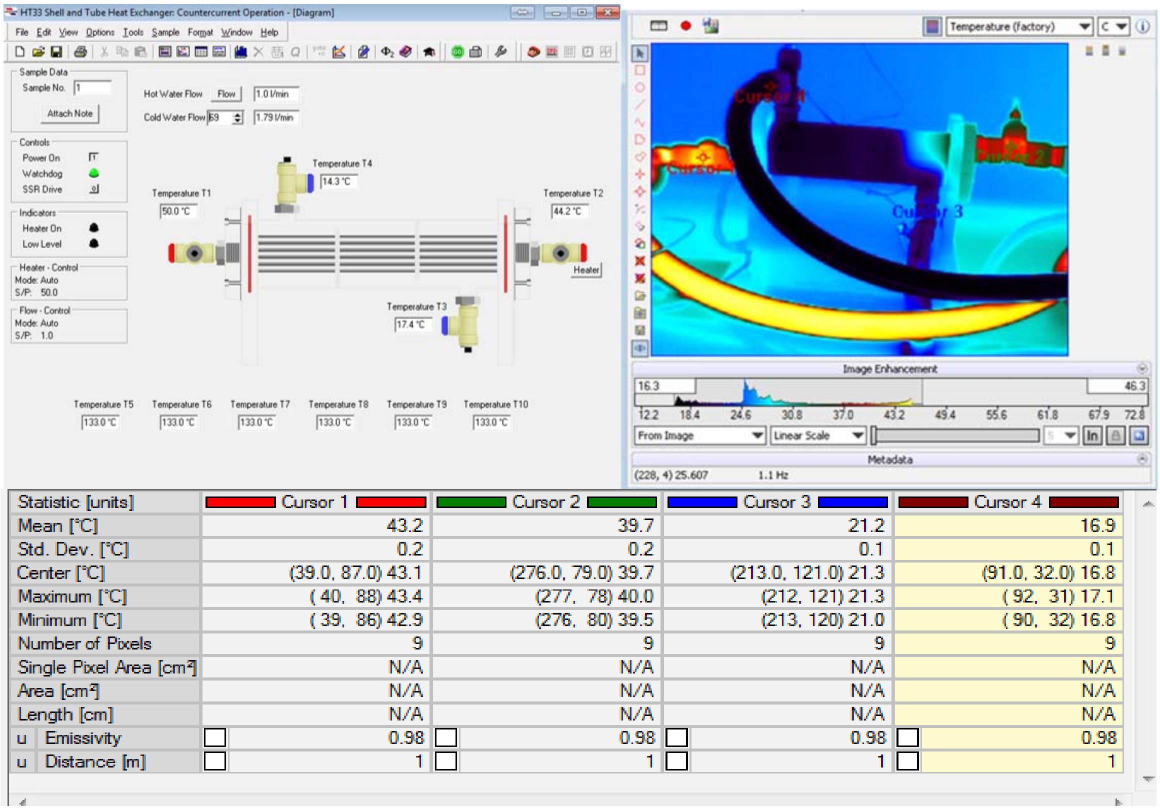

Figure 17: The provided desktop display the user used.

Within the broad paradigm of sustainable manufacturing, the issue of energy efficiency and conservation are addressed specifically in the workshop. We are focusing on increasing the efficiency of energy flows in manufacturing and industrial facilities with certain impact on both economic as well as environmental target variables. Inefficient energy use in manufacturing and industrial facilities is both increasingly expensive and unsustainable. Energy efficiency relates to reducing wasted energy, hence reducing energy consumption. Utilization of fossil fuels adversely affects the greenhouse gases released into the atmosphere and results in undesirable quantities of emissions. Increase energy efficiency will reduce the unwanted environmental effects produced by manufacturing and industrial processes. Controlling energy use is important, but it is also important to assess or estimate it, and to understand methods and approaches for reduction its use and for assessing the cost effectiveness of these measures. The workshop also includes an improvement of resource efficiency as well since these energy flows are typically directly or indirectly connected with the depletion of critical resources (oil, gas, coal). The topic “energy efficiency in manufacturing” is of major relevance from a nation as well as a single company. On a national scale, industry is a major consumer for 33% of the national electricity in US. There is a strong need of appropriate methods and tools to support fostering energy efficiency in manufacturing companies. The student training for manufacturing energy efficiency improvement has become a workforce development initiative for creating the next generation of engineers. The main objective of this workshop aims at contributing towards the improvement of energy efficiency in manufacturing and providing training for undergraduate students in industrial processes, energy assessment procedures, and energy management principles.

Evaluation Results and Discussion

Examination of the overall participants' performance for this particular event, it was noted that few students provided complete test information for either the pre- or post-test times. The use of the same exam for both occasions may have led to the some degree of increase on the difference scores for this particular sample given that it happened within one- to two-hour period. Overall, the large amount of material presented and the different groups who participated during the workshop session appear to indicate that various important concepts presented were captured; however, there may be still a need for a more structured curriculum that allows students to the better acquisition of the same. Even though, there was not statistical significance the participants were able to produce more than 5-point gains between pre-test and post-test administrations. As in previous workshop presentations, there is a need to improve the degree of relationship that exist between exam measures to make them more relevant to the concepts presented in their intent to assess students' level of concept acquisition.

CONCLUSION

All in all, the maiden launch of this project based learning course & technical & leadership workshop series appear to indicate that participating students gained a tremendous amount of new concepts and applications related to green energy, green manufacturing and life cycle assessment concepts. The workshops attracted a good number of graduate and undergraduate students with a larger representation derived from the undergraduate level group and those from the industrial engineering major or concentration. Some of the qualitative open-ended questions elicited similar comments and observations as indicating that the participants were satisfied or had acquired some new "knowledge", dispositions, and "skills" but these verbal comments were few and sparse across the different workshop presentations.

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