Chapter

Using ICT and Energy Technologies for Improving Global Engineering Education

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Abstract

Information, communication, and energy technologies have the potential to improve engineering education worldwide. With the availability of low cost, open-source microcontrollers/microcomputers, such as the Arduino and Raspberry Pi platforms, and a wide variety of sensors and communication tools, a range of engineering applications and innovations may be developed at a low price. Furthermore, the cost of solar panels and LED lamps have also dropped dramatically in recent years and these also allow for improved energy support in regions that lack energy access or require autonomous monitoring/processing. Also, low-cost 3D printers are now widely available for making simple prototypes of hardware. Finally, low-cost educational software tools have also become available. Combining these technologies enables engineering education to be brought into traditionally inaccessible communities in the world. In this book chapter, examples of how ICT and energy technologies are being used to teach students engineering technologies in underserved communities will be described. Application areas to be described will include environmental monitoring, clean water systems, and remote learning.

Keywords: ICT4D, open-source hardware, solar electric systems, 3D printers, Information and Communication technologies, sustainable development goals, global engagement

1. Introduction

Since the development of the first integrated circuit by J. Kilby in 1958 [1], microchips have advanced enormously growing to include billions of transistors on a single chip. These advances have fueled the growth of the information technology industry with high performance computers and high-speed communications. Data can be communicated at lightning speeds over fiber optic networks and stored in large data centers or in the cloud.

Yet, while these tremendous advancements are available to students attending universities in well-resourced settings, universities in low resource settings often lack even basic information and communication technology (ICT) infrastructure including computers, software, and Internet access. This lack of ICT resources greatly limits the quality of engineering education that can be delivered to students in these low resource settings. Many of the universities with low levels of ICT resources are in developing countries, especially in sub-Saharan Africa, Latin America and the

Caribbean, and in parts of Asia. This further exacerbates the digital divide between communities in low resource settings compared to those in higher resource settings. This results in limited innovation and modern economic development opportunities for students in low resource communities. Additionally, the lack of reliable electricity in low resource settings is another barrier to delivering quality education in these environments. Furthermore, the cost and energy requirements for conventional prototyping equipment, e.g. lathes, bandsaws, drill presses, etc. prevents them from being integrated into engineering curricula in low resource settings. Finally, the professors in these low resource settings do not have the training and education in the use of modern technologies. This results in much of the pedagogical approach to teaching engineering in low resource settings to be mostly theoretical and out of date. There has been very little opportunity for students to get hands-on prototyping experience that they can use to innovate engineering solutions to local societal problems.

Recent technology advances in the area of low-cost, open-source hardware and software are opening up new possibilities for professors at universities in low- and middle-income countries (LMICs) to provide their students with hands-on, experiential learning opportunities in developing engineering solutions to real-world problems. Microcontroller and microcomputer hardware platforms, such as the Arduino and Raspberry Pi platforms provide several input/output interfaces for sensors, displays, and transducers, significant memory storage, and quite powerful processing capability. When combined with an array of open-source software tools, such as the Linux and Android (a derivative of Linux) operating systems, Mozilla Firefox, Libre Office, Wikipedia, Khan Academy, Python programming language, etc. a powerful array of capabilities become available to developers at low cost. Furthermore, the cost of solar panels and solar electric systems have also come down dramatically over the last decade to the point where they are competitive with grid-generated electricity in many locations. This allows for reliable power to be provided in areas that have previously lacked access to energy. A fourth technology that has emerged over the last decade is the advent of low cost 3-D printers. This development has also added to the suite of low-cost technologies that are now available for low-cost prototyping of engineered products. Finally, affordable mobile phones are available everywhere. At a minimum, almost everyone in the world has access to feature phones and smart phones are owned by almost 50% of the world's population [2]. This ubiquitous availability of mobile phones throughout the world has provided relatively low-cost connectivity everywhere.

These five technological advances have opened many new opportunities for ubiquitous, project-based, learning of engineering, even in low resource settings. To fully take advantage of the opportunities afforded by the vision of Industry 5.0, a broader, more diverse array of engineers need to be educated to enhance the creativity needed to address broader challenges as described by the UN Sustainable Development Goals [3] or National Academy of Engineers Grand Challenges [4].

The focus of this chapter is to show how the combination of low-cost energy and information and communication technology (ICT) platforms along with 3D printers offer the opportunity to educate students in engineering in global, low resource settings to create a more inclusive and diverse workforce to support the Industry 5.0 initiative. Examples of hands-on initiatives in various LMICs including Nicaragua, Ecuador, Guatemala, Malawi, Sri Lanka, and Tanzania will be presented.

2. ICT, energy and 3-D printing technologies

Low-cost open-source hardware was first introduced by Arduino in 2005 [5]. The philosophy behind the development of the Arduino microcontroller was to make an easy-to-use platform for non-engineers to prototype electronic circuits. The basic Arduino Uno single board microcontroller (see **Figure 1**) plugs into the USB port of a computer and has its own integrated development environment (IDE) that is relatively easy to program (and can even be programmed with a basic, block-based programming tool). The features of the Arduino microcontroller are provided in **Table 1**. In addition to the basic device, there are shields that may be added to extend the capabilities of the Arduino microcontroller, such as a Wifi shield that allows for connectivity to a wireless communication network. There are also more powerful versions of the microcontroller, such as the Arduino Mega as well as devices of different form factor, e.g. circular devices that can be housed in circular housings.

A second open-source hardware device that has become very popular is the Raspberry Pi microcomputer. This low-cost device is a fully integrated computer. The features of the Raspberry Pi 3 Model B are illustrated in **Figure 2** and provided in **Table 2**. The Raspberry Pi has a built-in Google Chrome browser and supports programming in Python. There are also many application software packages that come with the basic device including Wolfram's Mathematica, MIT's Scratch, and Wikipedia. Many other software packages may be downloaded onto this microcomputer platform.

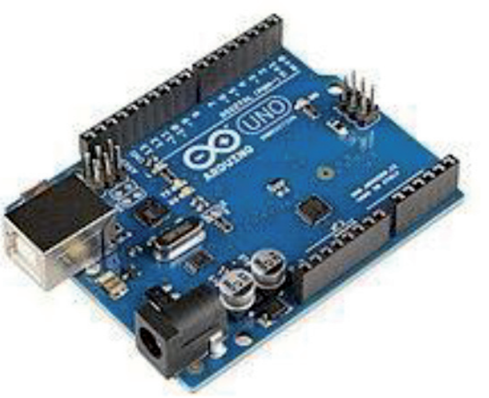

Figure 1.
Photograph of an Arduino Uno microcontroller [6].

Feature	Description
Processor type	8-bit 16 MHz Atmel AVR
Memory type	32kB Flash, 1kB EEPROM and 2kB SRAM
Analog Input/Output pins (includes PWM and SPI interfaces)	6
Digital Input/Output pins	14
Common input devices	Light sensors, temperature sensors, ultrasound sensors
Common output devices	LED's, LCD displays, motors, speakers
Size	Approx. 5 cm. x 7 cm.
Power supply requirements	3.3 V or 5 V input; 50 mA
Cost	~$20

Table 1.
Features of Arduino Uno microcontroller.

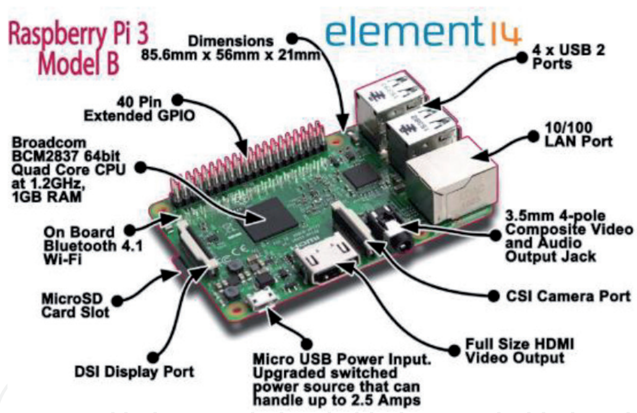

Figure 2.
Features of the Raspberry Pi 3 Model B microcomputer [7].

Feature	Description
Processor type	Broadcom BCN2837 64-bit Quad Core 1.2 GHz CPU
Memory type	1GB RAM + SD Card slot (up to 256GB)
Analog and Digital Input/Output pins	40 pin General Purpose I/O bus
Input ports/common devices	4 USB ports; Keyboard, mouse, display, camera
Output ports	Full HDMI video port, audio output port
Communication port	10/100 LAN Ethernet RJ45
Size	Approx. 9 cm. x 5 cm.
Power supply requirements	5 V input; 400 mA
Cost	~$35

Table 2.
Features of the Raspberry Pi 3 Model B microcomputer.

A third set of open-source hardware technologies that has emerged in the last decade is 3D printers. While 3D printers were available in university research labs in the 1990's, they were very expensive and so were economically out of reach of members living in low resource communities. The RepRap project was started in 2005 by Dr. Adrian Bowyer with the goal of developing low-cost 3D printers that could be replicated around the world [8]. This has led to the development of low-cost 3D printers that can now be purchased for under $200 in the US. Furthermore, open-source designs are available so that people can make their own units. **Figure 3** shows an example of a low-cost 3D printer available on the market today [9]. In addition to the 3D printer hardware, there are many open-source software tools, including 3D builder [10] that are easy to use by beginners. Also, free designs may be downloaded from various websites in standard file formats, such as.stl files. A comprehensive list of resources for 3D printing, including software tools, 3D printer models, example designs, etc. are available from github.com [11].

Many so-called "Fab-Labs" have now opened in many countries to take advantage of these industry trends to support open-source, low-cost design of engineered parts. In addition to 3D printers, these Fab-Labs include other prototyping tools in a workshop setting. A global mapping of Fab-Labs is available at the website: https://www.fablabs.io/labs/map [12].

Finally, the cost of solar panels has dropped dramatically in the past decade as shown in **Figure 4** [13]. This allows relatively low-cost solar electric systems (<$2 per Watt) to be installed in remote schools to provide consistent and reliable power even

Figure 3.
Lulz Bot Taz 6 low-cost 3D printer [9].

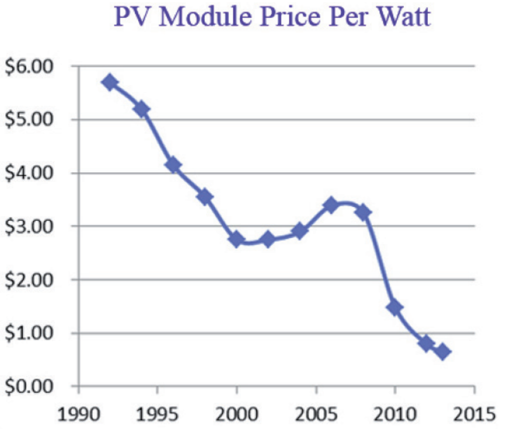

Figure 4.
Price of solar panels per watt from 1990 to 2015 [13].

Figure 5.
The "Digital Drum" solar-power computer kiosk in Uganda [14].

in areas that lack access to grid electricity. An example of a creative approach to setting up a solar computer kiosk is the "Digital Drum" that was developed by UNICEF. The design of the solar-powered computer kiosk employs modified oil drums to create the kiosk. A picture of this implementation at a school in Uganda is shown in **Figure 5** [14].

Bringing all these technological advances together offers the opportunity to educate students in low-resource settings in basic engineering skills. These students offer unique creativity and enthusiasm, resulting in a potentially more diverse array of products to emerge from these designers. There is a further trend in global engineering education where students from more privileged communities are interested in doing community service in low resource communities [15]. Students work with rural communities to identify needs and then co-develop engineering solutions for these communities [16]. These needs can span improving basic digital literacy in remote communities to developing applications to detect contaminants in drinking water. The next section describes more detailed case studies of improving engineering education in various universities in low resource settings.

3. Case studies of applying low-cost technologies in low-resource communities

Each of the subsections in this section focus on a particular application area framed by the UN Sustainable Development Goals (UN SDGs). The specific goals to be addressed here are:

- UN SDG Goal 3: Good Health and Well Being
- UN SDG Goal 4: Quality Education
- UN SDG Goal 6: Clean Water and Sanitation
- UN SDG Goal 8: Decent Work and Economic Growth

3.1 Enhancing the quality of education in low resource settings (UN SDG Goal 4)

3.1.1 Raspberry Pi workshops at Landivar University in Guatemala

The quality of education in rural communities is often very limited for many reasons including lack of trained teachers, lack of funding for the schools, and lack of technologies in the classrooms (including lack of connectivity). In 2009, World Possible, curated a package of creative commons resources (such as Wikipedia, Khan Academy, CK12 textbooks, etc.) for offline distribution to communities that lacked internet access [17] The organization coupled the content with the open-source web browser, Google Chrome, and created the Remote Area Community Hotspots for Education and Learning (RACHEL). They established this platform on the Raspberry Pi Model 3 and named it the Rachel Pi. The educational content stored in the unit's memory or on the micro-SD card could be accessed by computers, tablets or smart phones through a wireless router. Content on this device has been further developed in local contexts by local developers. A good example of this is the work done in Guatemala by Israel Quic, a native Mayan who produced materials based on his Mayan heritage in various Mayan languages for the local communities [18].

The Rachel Pi has been deployed all over the world from Tunisia, to Uganda to Papua New Guinea [19, 20]. A specific example is described in more detail next.

Landivar University is a Catholic, Jesuit university which has a campus in Quetzaltenango, Guatemala. The university is well-established and its professors in the Computer Science Department have a reasonably good curriculum including elective topics at a very basic level in the areas of artificial intelligence and Blockchain. The Arduino microcontroller is used in some project work at the university but only to a limited extent. However, the students and professors had not received any exposure to the Raspberry Pi until the author and his students conducted workshops at the university. Students at the university have access to laptop computers and the classrooms are well equipped with projectors and screens.

On the other hand, the region around the town of Quetzaltenango is very poor. Much of the population in the region is indigenous Mayan people who predominantly speak Quechua. The schools in the region of Totonicapan rarely have computer labs and many of them have no access to the Internet, although most of them do have access to electricity. The teachers also have limited technical skills. Catholic Relief Services (CRS) has been supporting a bilingual education program (in Quechua and Spanish) at the schools through a food and nutrition program as well as an infrastructure program (primarily building kitchens and latrines at the schools). The author and his students delivered two workshops on the Raspberry Pi to computer science students and professors at Landivar University in May 2019 and November 2019. Each workshop was held for two days. The first workshop provided an orientation to the Raspberry Pi and the second workshop was a more advanced workshop on configuring the Raspberry Pi for setting up a network and sharing resources from a server to individual computers.

The team from Landivar University working in partnership with a software engineer from CRS were able to obtain funding from the IEEE Humanitarian Activities Committee (IEEE HAC) [21] to establish a computer laboratory in a remote school in the community of Santa Maria Chiquimula in Totonicapan, Guatemala. This system was configured and deployed by the computer science students in early 2020 but because of the COVID-19 situation, has not been accessible to students and teachers at the school because the schools in the region have been closed since then. A photograph showing the students in the computer laboratory in early March 2020 as it was being set up is shown in **Figure 6**.

This example shows how a group of motivated university students in a low resource setting were able to address a local social challenge around the quality of education being delivered to school children in a remote, poor rural community.

A qualitative assessment of the November 2019 workshop on the Raspberry Pi was conducted. Two main questions were asked: What were the positive aspects of the workshop and what were the negative aspects of the workshop? The students indicated that they really enjoyed the practical, hands-on aspects of the workshop and the negative comment was simply that they wish the workshop had been longer!

3.1.2 Arduino workshops at Bluefields Indian and Caribbean University in Nicaragua

Engineering using the Arduino microcontroller can also be taught in low resource settings. Since the Arduino microcontroller may be interfaced to a variety of sensors and transducers, there is a large variety of possibilities for performing experiments with these devices. For example, the Arduino microcontroller can be interfaced to a temperature sensor and an LCD display and programmed to show

Figure 6.
Students at a school in Santa Maria Chiqimula, Totonicapan, Guatemala accessing content on a Rachel Pi server.

the ambient temperature of the environment. Another simple application is to use a light sensor as the input and display the ambient lighting level on an LCD display. More sophisticated applications, such as a line following robot can be produced by interfacing the unit to a mobile robotic platform and using a light sensor to follow a white line painted on the floor [22]. Another somewhat sophisticated application that offers students the opportunity to demonstrate their creativity is a wearable array of colored LEDs that are programmed to light up based on sound volume (through interfacing with acoustic sensors). There is a block programming interface to the Arduino microcontroller, like Scratch, that can be used with elementary/middle school children who are just beginning to learn basic programming skills for them to perform simple experiments with the Arduino microcontroller.

Bluefields is a town located on the Caribbean coast of Nicaragua. Most of the population in Nicaragua resides in the southwest, Pacific region of the country near the capital city of Managua. This part of the country has the highest economic development in the country while the Caribbean coast is relatively under-developed. The population of Bluefields comprises a variety of indigenous populations who are mostly fisherman. There are many social problems in this region and UNICEF has been working in this part of the country to pilot solutions to address these social problems, particularly as it affects children and youth. Bluefields Indian and Caribbean University (BICU) has as its mission to educate the minority students from the Caribbean coastal region (including Bluefields). Since the social problems affect members of the communities in the indigenous population, UNICEF established an innovation laboratory at BICU to support the university's students and professors to develop innovative solutions to local problems. While there is a computer science program and a computer laboratory at the university, it is relatively ill-equipped. The quality of education and resources in this university are significantly limited compared to the universities on the Pacific side of the country. In collaboration with UNICEF, the author along with his students delivered a two day workshop to the students and professors at BICU in May 2017. The first day of the workshop was focused on the Arduino microcontroller while the second day was focused on using Android Studio for developing mobile phone applications for Android phones [23, 24]. Arduino microcontroller development kits were donated to the university and the students were able to develop applications after the workshops were delivered. While no formal assessment was conducted following the workshops, the informal feedback provided by the students was that they were very excited by the hands-on, practical experience of building electronic circuits.

The students at BICU were so excited about designing and building electronic devices that they launched a robotics club later in 2017. The students from this robotics club competed and won a national robotics competition in 2018 as underdogs in the competition. As winners of the national competition, they were invited to compete in an international competition [25]. Many of the students at BICU were at-risk youth. Witnessing these underserved students' ability to embrace and apply electronics technology to win a national competition clearly demonstrates how the quality of education in low resource settings can be dramatically improved using low-cost hardware and effective mentoring.

3.2 Improving quality of health care in low resource settings (UN SDG 3)

3.2.1 Improving quality of health care in rural Nicaragua

The quality of health care in rural communities is often very limited. Community health workers (CHWs) with limited medical knowledge and training are often the front-line administrators of local health care to members of their communities. Rural medical clinics may also have limited facilities. Two examples of how quality health care may be improved in these rural settings using technology are described in this section.

The first example focuses on a project conducted in the rural part of northeastern Nicaragua in the area surrounding the town of Waslala. This region of Nicaragua is very poor and the community members in this area tend to be subsistence farmers who grow crops and raise livestock. The mountainous terrain is very rugged with relatively few paved roads as illustrated by the photograph in **Figure 7**.

The author and his students as well as students and professors from the M. Louise Fitzpatrick College of Nursing at Villanova University, worked with the local Catholic parish and two Nicaraguan universities to develop a telehealth system for this region [26]. The CHWs were trained to make basic measurements of blood pressure, temperature, respirations and, in the case of pregnant women, fundal height. In the case of babies, they were also taught to measure baby head circumference and baby weight. All these trainings were done by the Nursing professors and students from both Villanova University and a partner university, the Universidad Nacional Autonoma de Nicaragua (UNAN) branch in Matagalpa, Nicaragua. The CHWs were then trained in texting the collected vital sign data to a central database on a computer server that was located at the Universidad Nacional de Ingenieria (UNI) in Managua, Nicaragua. They were also trained in using solar chargers to recharge their cell phones since many of the CHWs did not have access to electricity in their communities. An application program was written using an open-source UNICEF software tool, RapidSMS, that could accept text messages and display them as patient records in a database. This data could be reviewed by trained health care professionals and feedback provided to the CHWs in case a patient needed medical attention. While the initial software application was developed by students at Villanova University, further development of the software was conducted by students from UNI. These students were able to use the open source software to again address real world challenges having understood the context of the communities through engagement with the community members and the CHWs. The students performed competently and really enjoyed the experience of doing hands-on, practical application development using open source software to address a social need.

The telehealth project was further expanded to other regions in Nicaragua. One particular expansion was to the under-served Caribbean coast and students from BICU were engaged in the software development. Since RapidSMS requires significant programming skills (that were somewhat lacking at BICU at the time), a simpler cloud-based software tool, Rapid Pro, also from UNICEF, was used in this application. A comparison of these two software tools for telehealth project development is provided in [27]. Health care software tools are growing extensively

Figure 7.
A photograph of farmers in the Waslala region of Nicaragua.

worldwide to enhance the quality of healthcare in under-served communities. A good example of this is the DHIS 2 health information management system that is being used in many LMICs throughout the world [28].

3.2.2 Teaching students to repair medical equipment in low resource settings

Repairing medical equipment in low resource settings can be challenging because of the lack of availability of spare parts. This is because, oftentimes, the equipment is old and spare parts may not be available. Furthermore, medical instrumentation can also be difficult to obtain in low resource settings because of lack of funds. In these cases, 3D printing becomes an option to print replacement parts as well as medical instruments. A start-of-the-art review of additive manufacturing of medical instruments was published by a group of researchers from the Delft University of Technology in the Netherlands [29]. While this paper provides a very comprehensive review of a range of medical instruments that may be 3D printed, for the purposes of low resource settings, some basic tools are shown in **Figure 8**. The figure shows a surgical kit comprising a scalpel, hemostat, forceps, and tweezers. This is particularly important in low resource settings since there may be a very limited supply chain to remote medical clinics. In many developing countries, the medical system is a national system and remote clinics often receive little funding from the central government. Local production of these instruments allows surgeons to be able to have low-cost but very capable tools for their use.

Additionally, local doctors can develop their own instrument designs based on their needs and therefore promotes more local creativity in the design of medical instrumentation.

3.3 Clean water confidence indicator (UN SDG goal 6)

Chemical and biological contamination of water sources is a major problem all over the world. A low cost means of disinfecting water in remote communities is to put the water into a bottle and place it in the sun for a period of time. In this solar disinfection technique, the UV radiation from the sun kills bacteria in the water resulting in potable water for drinking [30]. Yet, while there are some indicators that can show that the water has received sufficient treatment, these are relatively expensive or may need periodic replacement.

An innovation developed by students at Villanova University uses a UV sensor to accumulate the UV radiation using an Arduino microcontroller. When the

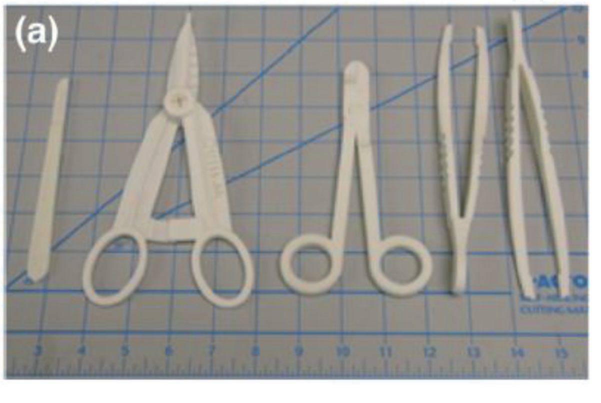

Figure 8.
Common medical instruments printed in a 3D printer.

accumulated UV radiation crosses a threshold, an indicator displays that the water is safe to drink. This system can be used for several bottles at a time in a community setting [31].

Another example of using an Arduino microcontroller to evaluate the quality of water for potable consumption was described in [32]. The authors of this paper from Brunei used an array of sensors, including a turbidity sensor, a total dissolved solids (TDS) sensor, a pH sensor and a temperature sensor that were interfaced to an Arduino unit as shown in **Figure 9**. The unit was tested in a stream on the Universiti Brunei Darussalam campus. Preliminary results of their system show good promise for assessing water quality, but they are planning to upgrade the system to incorporate a Raspberry Pi microcomputer to give remote data collection and more powerful computation capabilities.

3.4 Enhancing productivity and economic growth (UN SDG 8)

3.4.1 Soil moisture sensor design

Precision agriculture is becoming an important area in farming. While this technology has been applied to large holder farms it is still in its infancy regarding small holder farmers. One area of importance in small holder farms in developing countries is only irrigating farms when soil moisture content falls below some threshold value. Combining moisture sensing with drip irrigation technology offers the opportunity to minimize the amount of water used in irrigating farms.

Engineering design instruction at the University of Malawi Polytechnic in Blantyre, Malawi used to almost exclusively focus on paper designs because of the lack of prototyping materials and facilities. This meant that the students would just work on the first half of the design process, i.e. understanding the problem, brainstorm design solutions, settle on a particular solution and then sketch out the solution. They did not get to prototype the design, test and troubleshoot it, or iterate on design improvements [33]. Through a collaboration with Rice University in the US, a maker space facility was established at the University of Malawi Polytechnic in 2016. This Polytechnic Innovation Design Studio (PIDS) includes a variety of prototyping equipment Arduinos and Raspberry Pis, 3D printers, a laser cutter, a CNC machine, and hand tools. These tools are used at all levels beginning in the first-year design classes through to the final year capstone design classes in both the electrical engineering (EE) and mechanical engineering (ME) curricula.

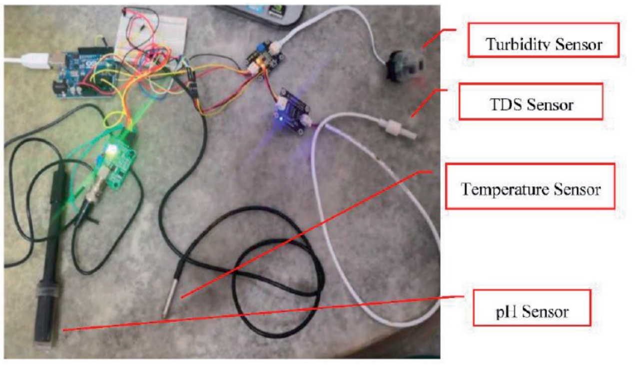

Figure 9.
Picture of Arduino-based water quality sensing unit.

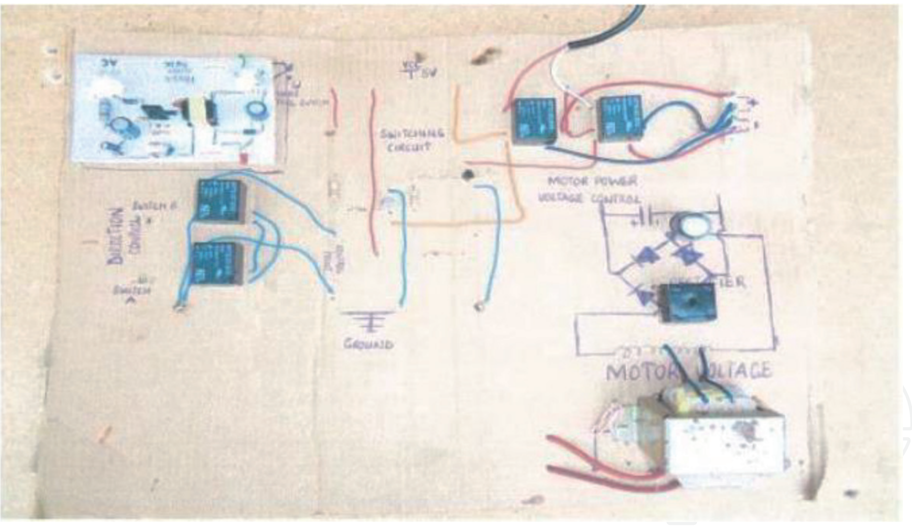

Figure 10.
Pre-PIDS circuit prototype using a cardboard backing and organizational structure for the circuit [33].

Figure 10 shows a highly rated EE student prototype circuit design prior to the establishment of the PIDS facility. The design includes the circuit components mounted to a cardboard backing. After the PIDS facility was established, the designs were significantly improved. **Figure 11** shows a moisture sensor using an Arduino microcontroller as part of a drip irrigation system to minimize water use in irrigating farms. Clearly, the quality of the design is much more advanced than the prototype circuit shown in **Figure 10**.

An assessment of the quality of the prototype and design process level were conducted for both EE and ME students using a five-point Likert scale. **Figure 12** shows the results of this assessment. The prototype quality has been seen to considerably improve by the presence of the PIDS facility. The change in the design process level was also observed to improve but the upper end of the design process levels did not change.

3.4.2 Improving productivity of small and medium sized enterprises in rural parts of Europe

An interesting approach to teaching 3D printing to remote communities is the Fab Bus mobile STEM education platform developed in Aachen, Germany [34]. This mobile education unit is deployed in a converted double decker bus as shown in **Figure 13**. Eight seats on the upper deck of the bus house 3D printers for students and a teacher's seat. There are also computers at each station with 3D CAD software

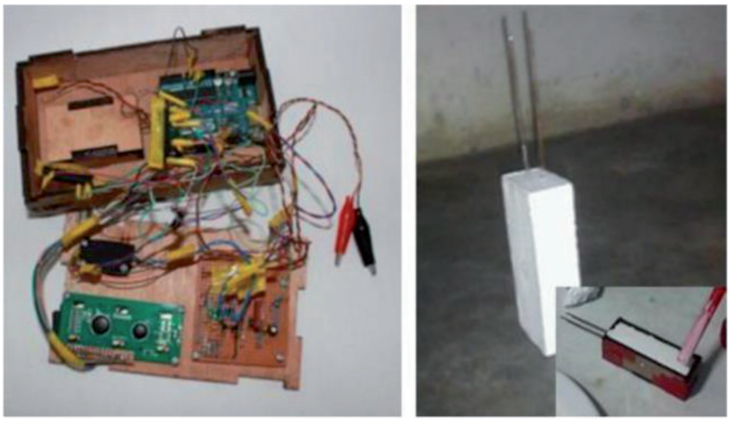

Figure 11.
Soil moisture sensor and Arduino reader with LCD display [33].

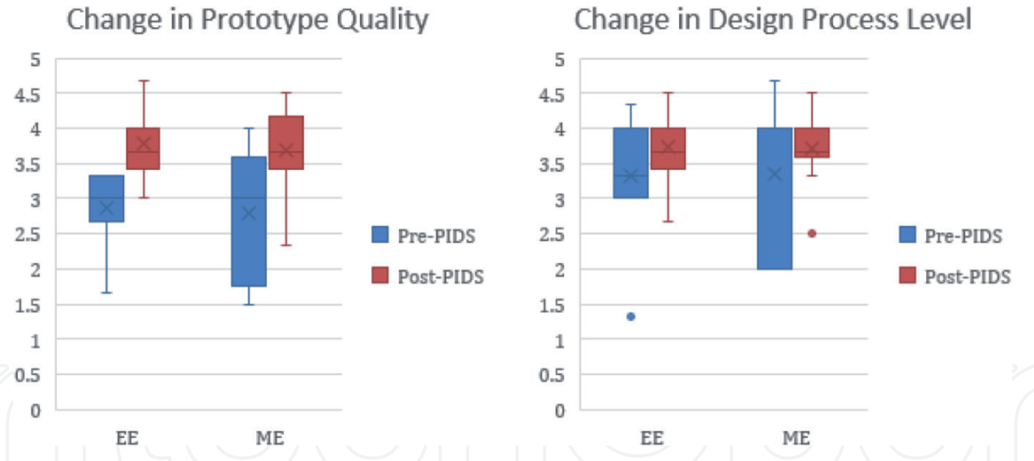

Figure 12.
Assessment results for pre-PIDS and post-PIDS designs [33].

Figure 13.
Mobile 3D printing educational unit (Fab Bus) [34].

tools. The upper deck can be used as a classroom to teach students how to design and print 3D models. A layout of the upper deck is shown in **Figure 14**. The lower deck houses a showroom with industry-grade machines and various professionally made parts, including metal parts. Short courses are taught in this mobile classroom to high school and university students as well as to small and medium sized businesses.

Figure 14.
Upper deck layout of the Fab Bus [34].

This innovative teaching platform has toured three countries – Germany, Belgium and the Netherlands and has been well received in all three countries.

4. Conclusions

In his best-selling book, "The World is Flat", journalist Tom Friedman observed that a youth with access to a computer and the Internet can contribute to economic development from anywhere in the world [35]. Fifteen years since the first edition of that book, this statement is even more true. Industry 4.0 brought us massively interconnected devices which led to the accumulation of large amounts of data (so-called "big data") that required artificial intelligence and machine learning to interpret. Industry 5.0 is bringing humans back into the equation to work with machines and is the motivation of this next phase of the industrial revolution. The ubiquity of low-cost ICT and energy technologies as well as low-cost manufacturing technologies, offers an opportunity to bring a more diverse youth, including those from low resource settings, to be educated in engineering product development and to thereby contribute to local economic development.

The technology trends in low-cost ICT technologies, including ubiquitous access to mobile phones, low-cost energy access via solar panels, and open-source software and hardware systems have been reviewed in this chapter. A few application sector examples, built around the UN SDG frameworks, including quality education, clean water and sanitation, good health and wellbeing, and decent work and economic growth have been explored. These technological developments are driving a revolution in global engineering education bringing in historically neglected youth into the worldwide community of engineers. This creates the potential for unique and potentially transformative solutions to global challenges to be invented by students from low resource settings given their unique perspectives on the world.

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Conflict of interest

The author declares no conflict of interest.

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