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Using IoT for Sustainable Development Goals (SDG) in Education †

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Abstract: Whereas the demand of pure Science, Technology, Engineering and Mathematics (STEM) jobs is increasing, young people interested on STEM studies are decreasing. Among the reasons, different studies show that male and female students do not have a clear perception of engineering. Furthermore, there is a very worrying gender gap in fields as Computer Science. The lack of role models, stereotypes and the perception of a machine and programming oriented discipline are pointed out as possible reasons. In order to reverse the situation, this paper presents an ongoing project to be conducted at the early years of high school to connect computer engineering with environment giving the students the idea that computer engineering is not only about programming and giving them real-life applications. Then, the project serves of Internet of Things (IoT) and Sustainable Development Goals (SDG) to propose students a real world problem to face and promote engineering vocations. One of the key aspects of the project is to be directed to young students. This increases the impact in both number of students attending the activity and the possibility that teachers accomplish actions against the gender gap before it is well established.

Keywords: IoT; education; engineering; gender gap; SDG

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1. Introduction

The skills students develop at Science Technology Engineering and Mathematics (STEM) are very important for an ever-changing and complex word where the Information and Communication Technology (ICT) sector has a key role in economic development. Today, engineers across a host of different fields from the traditional electric and mechanical engineers to the more recent robotics, artificial intelligence or big data engineers are building the present and future of the world. However, engineers demand is finding a lack of human workforce.

Today, there are many initiatives to encourage students to pursue STEM-related careers. Specially the focus has been put on women as they represent a minority of the engineers workforce worldwide [1–4]. Actions are directed to reduce the loss of female talent from the secondary school to the professional career, often represented as a leaky pipeline [5].

Perceptions of secondary school students towards engineering have been considered in the literature [6]. As a result, students in general do not have a clear perception of engineering. However, boys are more likely to pursue STEM studies than girls. Among the reasons for the gender gap usually found in the bibliography are the stereotypes and the lack of role models. However, a study on ICT also showed that boys view Computer Science (CS) more human and application oriented than girls do [7]. A huge European survey revealed that most young European women become attracted to

STEM between the ages of 11 and 12. But that interest then drops off significantly between 15 and 16, with limited recovery [8]. Therefore, actions oriented to engage students in solving real-world problems with STEM at the early courses of high school could contribute to promote the interest in STEM studies specially among girls.

In 2015 United Nations signed the Agenda 2030 for Sustainable Development (SDG), trough 17 Sustainable Development Goals [9]. The Internet of Things (IoT) could be a game-changer for sustainability and gender equality. This work presents a project devised for high-school students working on the following SDG objectives:

- SDG 7, *Ensure access to affordable, reliable, sustainable and modern energy for all*, as the application focused on saving energy, this fact will help to allow electricity access to everyone.
- SDG 12, *Ensure sustainable consumption and production patterns*, energy consumption is one of the most critical products that people demand and also has a big impact on the environmental footprint.
- SDG 13, *Take urgent action to combat climate change and its impacts*, it has been demonstrated that energy production is affecting climate change, for this reason been aware of how energy can be save would also help on this goal.
- SDG 5, *Achieve gender equality and empower all women and girls*, through the way that the experiment has been developed, we want to approach more women to engineering, as there exists a worrying gender gap on this field critical on the human development and affecting directly to the society.
- SDG 4, *Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all*, giving equal opportunities to every citizen is one of our objectives, for this reason, the practices we proposed would apply to public schools and will help teachers to improve their teaching skills.
- SDG 17, *Strengthen the means of implementation and revitalize the global partnership for sustainable development*, the interrelationship between goals has been demonstrated in all previous paragraphs, they cannot be seen isolated, they has to be worked together. Synergies with different agents are shown in our approach: engineers, high-school students, high-school teachers, applying finally to the society.

The main goal of the ongoing project proposed in this paper is high-school students perceive CS as not only machine- and programming-oriented discipline but real-life problem solving and become aware of sustainable development.

In the following section, we will describe the architecture of the system and design considerations. In Section 3, the practical activities proposed to students are described. Next steps previous to the extent use at high school and the impact evaluation planning are described in Section 4. Finally, conclusions are presented in Section 5.

2. IoT Sustainable Development System

Presently, the average age at which mobile phone use begins is 10.3 years [10]. They are generally used for communication, games, entertainment and task-oriented activities. Mobile app development offers the possibility to bring young people sustainable development goals. Furthermore, IoT devices and rapid development boards can combine to create innovative do it yourself (DIY) projects .

The IoT sustainable development project consists on measuring the electrical consumption of different bulbs and ambient parameters as temperature, humidity and level of CO_2 inside homes. The former allows to account on the differences between led and incandescent technologies at cost savings and CO_2 emissions. The last is intended to young people aware of the importance of air quality, comfort and energy efficiency in construction and responsible consumption.

2.1. System Architecture

The design involves the following devices interconnected (Figure 1):

- Raspberry Pi 2 Model B with Raspbian Strech
- WiFi Adapter TP-LINK TL-WN722N
- CO2S-W sensor
- 2 Smart sockets TECKIN SP22
- Android Smartphone
- Computer

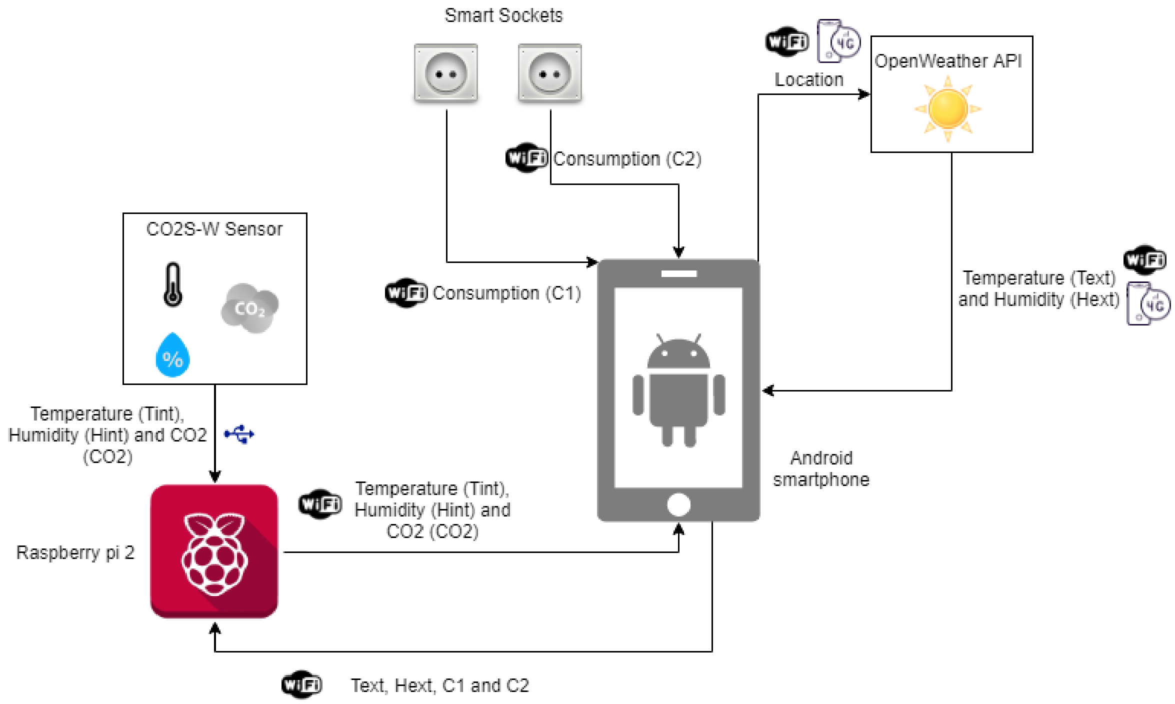

Figure 1. Architecture of the system

One of the components of the system is the CO2S-W sensor that measures the temperature (Tint), humidity (Hint) and CO_2 level (CO2) inside the house. This sensor is connected through a USB-Serial converter to a Raspberry Pi 2 where a web server is hosted.

A new Android application has been created so the Android smartphone can collect and show all the data to the student. This data includes, the temperature (Tint), humidity (Hint) and CO_2 (CO2) level inside the house, the temperature (Text) and the humidity (Hext) outside the house and the data of the smart sockets (C1 and C2). All this information is sent to the server on the Raspberry Pi where it is stored in a local database. To get the weather outside the student's house, the application sends a request to the OpenWeather API using the latitude and longitude obtained by the GPS of the smartphone.

To get the data from the smart sockets, the firmware of these sockets has been modified so the data of these sockets can be intercepted making one request to the IP direction of the socket. This data includes current, voltage, power, energy and the state of the smart socket.

To develop this system it has been implemented the following software:

- In the Raspberry:
    - Web server using Python, Flask, HTML, CSS and JavaScript to receive and show the data of the different components of the system.
    - A script in python to read the data from the CO2S-W sensor and store it in a local database.
    - A local database using SQLite3.
- Android app using Android Studio (Java) to collect the data from the smart sockets and from the weather API and send it to the server on the Raspberry.

2.2. System Cost

The cost of the whole system is very important in order to determine its viability as an education equipment. Furthermore, it has to be taken into account that students are using the kit at home without the teacher's supervision. Consequently, it could be more easily damaged.

We consider that every student has a smartphone and a PC or tablet. Otherwise, they should be included in the budget. Then, the system cost can be approximated as:

Table 1. List of devices and cost.

Item	Cost (Euros)
Raspberry Pi 2 Model B	35
Raspberry Pi 2 power supply	7
Raspberry Pi case	5
Micro SD 16 GB	4
WiFi Adapter TP-LINK TL-WN722N	10
CO2S-W sensor	123
Cable USB with embedded UART 3.3V	19
2 Smart sockets TECKIN SP22	25
Total:	228

To sum up, according to Table 1, the cost of the system rises around 228 Euros. This amount could be reduced by using lower cost devices, specially the CO2-W sensor.

2.3. Installation

The student would receive a configured Raspberry pi and Smart Sockets. However, it is possible to build the project from scratch. See the steps at https://sites.google.com/view/consumoco2eiot#h.p_AwTGIH_fgu3w. This involves the raspberry pi configuration (wifi, ssh service and required libraries). In addition, the smart sockets have to be reflash to connect to the project's wifi. See the details at https://github.com/ct-Open-Source/tuya-convert.

In case the system has been previously configured, students only require to take two simple actions:

- Install the *Co2yConsumo* App: this application allows to access to the smart sockets, read the ambient parameters and send data to the server on the raspberry pi. This can downloaded from https://drive.google.com/open?id=1o57t7x9MQ3XAGTvscprfj3cr8C9ogx8x.
- Interconnect the system: a WiFi hotspot has to be configured using the smartphone (name: *ProyectoIoT* and password: *consumoIoT*). As the raspberry pi and the smart sockets are already configured to connect to this wifi, the students only need to connect a pc to the *ProyectoIoT* wifi to allow access to the web server. As a result, all the devices are now interconnected.

The last step is to launch the data collection and web server. This can be automatically launched at start up. However, students can also follow the steps described at https://sites.google.com/view/consumoco2eiot. Therefore, students access to the raspberry pi shell to download the code available at https://github.com/LauraOliva/Consumo-CO2-IoT/blob/master/consumo.tar.gz and run the scripts.

Once the server is launch, the data stored in the Raspberry pi can be observed opening a web browser with the url http://192.168.43.42:5000/graph. See Figure 2.

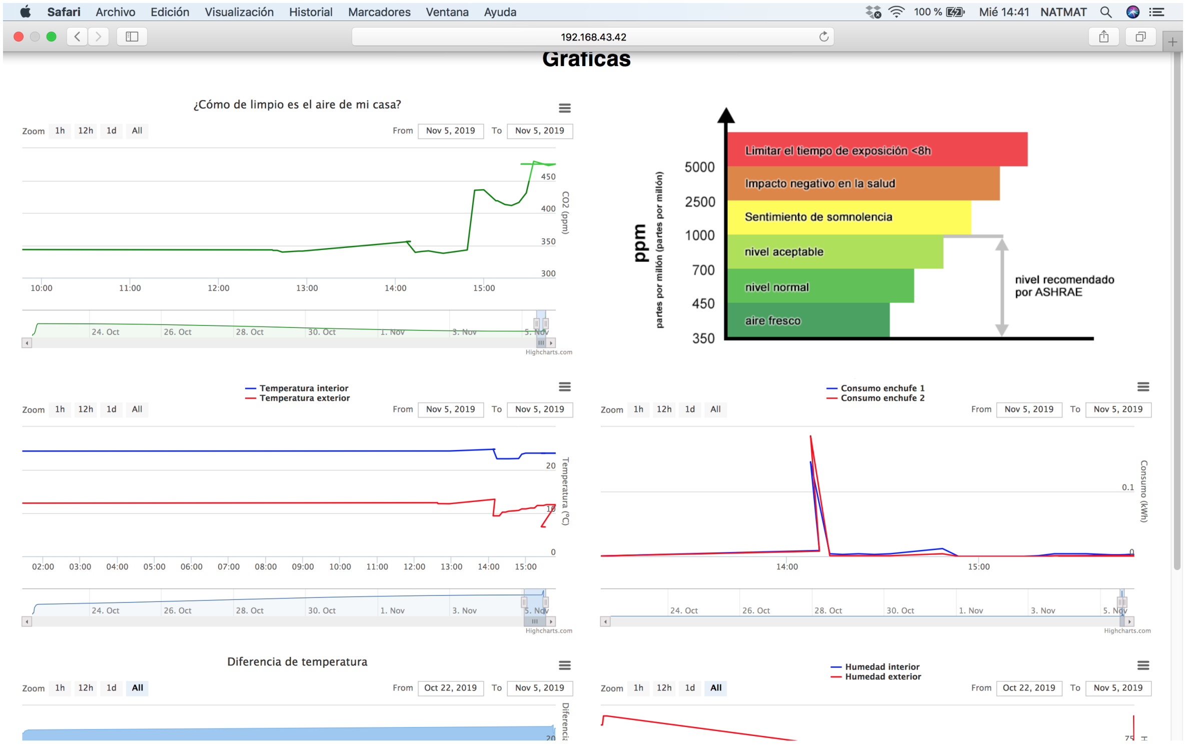

Figure 2. Webite to represent sensor's data.

Moreover, the smartphone app has 3 different tabs to show data and control the smart sockets (Figures 3 and 4):

- Outdoor data: weather data at the current location
- Indoor data: data collected by the sensor connected to the raspberry pi
- Data from the smart sockets: voltage, current, power and energy of the devices connected to the plugs. The smart sockets can be powered on/off using a virtual button

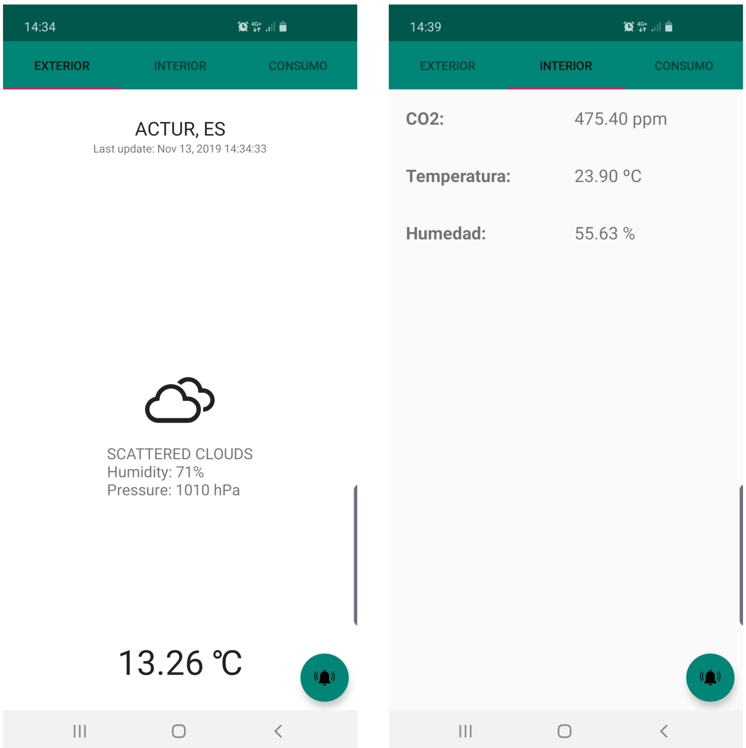

Figure 3. App ambient parameters tabs. (**Left**): Outdoor weather from OpenWeather API and (**Right**): indoor data from sensors.

All this data is automatically sent to the raspberry pi server. In addition, the application allows to add alarms to get notifications. e.g., a notification can be received if the CO_2 level at home is greater than 700 ppm (Figure 4).

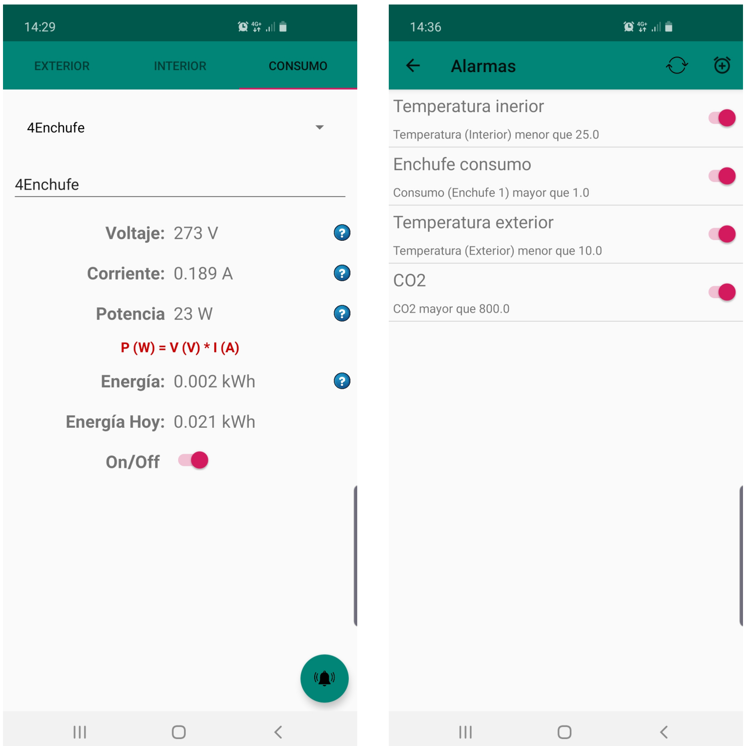

Figure 4. App smart sockets and alarms tabs. (**Left**): smart sockets where ? mark details the formulas in red colour and (**Right**): alarms.

3. Case Study: IoT Sustainable Development Project for High-School Students

The main goal of the following exercises is to show the students how to save energy and, thus, save money in the electric bill at the same time that the student learns how to reduce the emission of carbon dioxide. Besides, with exercise 3 the student would also learn how different factors can affect comfort and consumption. Being this activities accomplished at home, students can feel more protagonists and share the experience with their families. This is also very important.

The difficulty of the exercises is increasing from exercise 1 to exercise 3. In the first exercise, the student would receive the formulas necessary to make the calculations and then only focus on one measurement, the consumption of the devices connected to the smart sockets. In the other exercises, the student would have to think about how other factors can affect to the sensors read and test actions to save energy.

As a result of every exercise, students have to complete an online test. This is automatically evaluated giving feedback to the student. In addition, teachers can supervise the results and interview the students during or after the activity.

3.1. Exercise 1: Led vs. Incandescent Bulbs

The main goal of this exercise is the students can observe that a simple change of technology can help to save energy, money and reduce CO_2 emissions.

In this activity, the student will have to use two smart sockets. A lamp with an incandescent light bulb will be connected to one smart socket and a lamp with a low-energy bulb will be connected to the other smart socket. Then, the student will have to calculate the amount of energy saved. In addition, the cost savings including the price of the bulb will be calculated. In doing so, they will need to use the electricity bill to see the electricity costs. Besides, students will translate the calculated savings into CO_2 emissions reduction for a supposed situation. Consequently, they could be aware of responsible consumption.

As a result of the activity, students have to upload a picture with the graphs of a 5 min bulbs' consumption and complete a test with the calculus of energy, costs and CO_2 emissions.

3.2. Exercise 2: Construction and Consumption vs. Comfort

The objective of this activity is that students be aware of the recommended thermal comfort and can relate it with electrical consumption. In addition, they can realize how construction can significantly affect the required energy. Concepts as energy efficient housing or passive house can be introduced.

To do this exercise the student would need one or more smart sockets and, depending on the season of the year, a fan, an air conditioner or a heater. The student would connect this device to the smart socket to measure the consumption of this device and analyse how other factors such as the isolation of the house or the difference between the temperature outside the house and the temperature inside the house, effects on the device consumption. In addition, the student will test different tips to save energy.

As a result, students have to upload a picture with the graphs of a 5 min fan or radiator's consumption together with different indoor/outdoor temperatures. e.g., indoor at 20 and 25 degrees in summer at midday (outdoor temperature of 35 degrees) and midnight (outdoor temperature of 20 degrees). Students have to submit a brief analysis of the data and conclusions. This activity also serves to students discuss in groups about the observed results. This can highlight that depending on the type of construction, energy efficiency can change.

3.3. Exercise 3: Air Quality

The main goal of this exercise is that the students learn the recommended levels for temperature, humidity and carbon dioxide inside home and how they can be maintained.

To do this exercise, the student will need only the Raspberry Pi and the CO2S-W sensor and the alarms configuration. Then, the student can set some alarms to receive a notification when one of the reads leaves the comfort zone. They can test different actions to maintain the levels inside the recommendations.

As a result, students have to upload a picture with the graphs of a 24 h record of these parameters and submit a report with an analysis of the data. This exercise is intended to be discussed in groups to determine best practices to be adopted at home.

4. A 2019–2020 Course Pilot

The project presented in this paper is considered to be part of high-school curriculum. The reason is very clear. A blog or academy with this kind of projects is usually only attended by previously motivated people and plenty of DIY activities can be found in Internet. Our purpose is to reach to a broad mass of students. In doing so, the collaboration of teachers is crucial. Therefore, it is necessary they participate in the design of the activities in order they succeed. Besides, teachers must be aware of the gender gap in STEM in order they can pay attention to stereotypes, the lack of female references or even encourage girls to pursue STEM studies.

Therefore, during the first term of academic year 2019–2020, the project will be revised by a group of technology teachers in order to adapt it to the typical high-school environment. Thereafter, at the second term, this will be used in the technology classes.

It is very important to measure the impact of the activities in terms of engineering perception, awareness of sustainable development and the activity itself. They will also contribute to analyze interest on engineering studies and gender gap. Then, a pre-activity and post-activity questionnaires will be designed in order to measure it. Questionnaires will be anonymous but, previous and posterior ones will be correlated by the use of a code. They could include statements as "I consider to study engineering", "I think that computer science can be used for reducing CO_2 emissions" or "I consider to develop my own mobile applications". Moreover, word associations with engineering, gender or sustainable development can also be used to measure the impact [11].

5. Conclusions

SDG objectives and IoT can collaborate to increase the interest of young people to engineering and reduce the gender gap.

This paper presents a novel project designed to young high-school students about 12 years old that apply technology in a real world problem. They will be aware of responsible consumption and environment together with their own capability to problem solving through technology. Part of the success of the project is that it takes place at school and teacher are involved. This assures the broad mass of students have the same opportunities.

This ongoing project will be tested during the academic course 2019–2020 with the participation of secondary school teachers. Promising results are expected as practice experiences have a high impact on young people.

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