Facilitating Theoretical and Experimental Internet of Things Learning in Higher Education Using a Novel Flexible-Web Platform

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ABSTRACT

*Given the rapid growth of emerging new ICT (Information and Communications Technologies) and their penetration both in the industry and in the home, there is a need for greater familiarization of people with these new technologies. To cover this technological gap, a flexible web platform was developed as a support tool for learning IoT (Internet of Things) by integrating embedded hardware and IoT platforms in the cloud to complement, in a practical way, the teaching of this technology at different levels of the higher education. The platform called *SimpleIoT* has three levels of complexity: basic, intermediate and advanced, which allows students without prior knowledge of ICT to advanced students in the area to take advantage of the resources it has. Instructors who teach subjects related to IoT can use it as a useful tool to better conceptualize the teaching of this technology. In this sense, *SimpleIoT* was used as a support tool in an elective course called "*Discovering the IoT and its applications*" offered to one hundred second-year students of non-ICT-related careers at Tecnologico de Monterrey. The results show that more than 90% of the students see the platform as a useful tool in learning IoT and, in addition, they believe that the information offered by the tool is relevant and can be used at some point in their careers.

CCS CONCEPTS

• **Social and professional topics**; • **Professional topics**; • **Computing education**; • **Computing education programs**; • **Information technology education**; • **Applied computing**; • **Education**; • **Information systems**; • **World Wide Web**; • **Web services**;

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KEYWORDS

Web platform, Internet of Things, IoT, higher education, educational innovation, ICT, Industry 4.0

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1 INTRODUCTION

The impact of technology on the future of humanity is such that it can be considered as a primary force that marks global megatrends. In this framework, a phenomenon known as Industry 4.0, Internet 4.0 (abbreviated as I4.0) or also called Fourth Industrial Revolution arises, which can be defined at a general level as "the explicit government commitment to promote a set of technologies and frameworks, legal and cultural, necessary to take advantage of its maximum potential" [1]. Seen from a technical point of view, this set of technologies are cyber-physical systems that are made up of a physical system controlled by computers and the Internet [2]. In a large part of the current technological trends, the implementation of these systems is observed, which in turn are made up of three main pillars: the phenomenon of big data, cloud computing and the concept of Internet of Things [3].

For universities, the above trends have become so ubiquitous that the state of the art encourages teaching technology with technology and promoting logical thinking methods for their students [4, 6]. As Lamprou mentions [5], there is an existing gap between early adopters and early majority for these innovative teaching methods. Furthermore, it is important that students of all careers are familiar with information technology regardless of their area of study and can understand its use at different levels of depth, to establish direct connections with their profession [7, 8].

Due to this need, this project focuses specifically on the Internet of Things phenomenon, which is characterized as the presence of a set of sensors and actuators capable of cooperating in a defined system. IoT was specifically chosen for its accelerated growth, high market penetration and unparalleled disruption [9, 10], the project consists of an integrative platform for learning the various technologies to carry out IoT projects, which integrates various hardware options, different forms of wireless communication and various

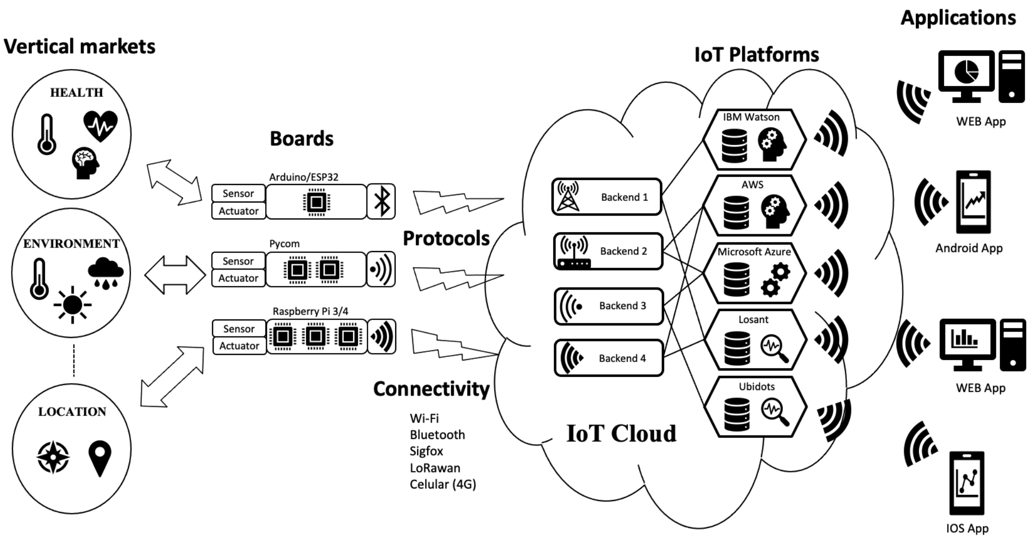

Figure 1: The IoT Educational Platform Concepts

cloud service options for data processing. In this platform there are different levels of depth to carry out basic practices through simulations, intermediate with cards and databases and advanced ones that already include communications and application programming.

2 DIDACTIC IOT WEB PLATFORM

In learning emerging technologies, such as IoT, there are different platforms that instruct the user on the connection and use of different devices for IoT projects, but normally they only instruct on the use of a specific device or on the platform from which the company owns. There is no integrating platform on the market that instructs on the use of the main technologies for IoT projects; In addition, there is an enormous diversity of development boards, types of wireless communication and IoT services in the cloud that make it difficult to select the most suitable elements for a specific IoT project. To solve this need, a flexible didactic platform was created, called *SimpleIoT* (http://itecstraining.com/plataformaiot/index.html), which serves as a support tool in the teaching of IoT for undergraduate students.

2.1 Educational IoT concepts

In the development of the didactic platform, a scheme was defined that considers four essential components (IoT concepts) that a student could learn from IoT technology in order to apply it in a vertical market:

- **Hardware.** Development boards and embedded hardware that acquire information from sensors and manipulate actuators. They obtain and send information as scheduled.
- **Connectivity and protocols.** The communication protocols that boards use to communicate with other devices. Each protocol is distinguished primarily by its data transfer rate or by the extent of the links.
- **IoT platform in the cloud.** Services provided by third parties, responsible for processing and redirecting the information produced in the system.
- **Software development.** Web or native application for PC, iOS or Android devices for visualization and modification of data in an intuitive and human-friendly way.

Figure 1 shows the interrelationship of the aforementioned concepts that are taken into account in the development of the web platform.

2.2 Web Platform description

The web platform was designed in such a way that it allows users to choose the most appropriate options for the IoT project that they want to implement and thus reduce their learning curve in connecting and handling the technologies associated with IoT. The platform structure, shown in Figure 2, consists of four main sections that are described below.

2.2.1 Assistant. Through the Assistant, a novice or ex pert user can enter the characteristics of the IoT project and obtain the necessary information to carry it out. The way to define IoT projects depends on two options that the user can choose:

1. Selection of development board. In this mode, the user enters the needs of the IoT project by assigning values to their requirements for digital and analog pins, PWM (Pulse Width Modulation), operating voltage, input, operating speed, wireless protocols and serial communication. It is assumed that the user does not know what technologies it will use, so it is aimed at newcomers. The objective of this modality is to propose to the user a possible solution to accomplish their project.

2. Connection to IoT cloud services. In this mode, the user enters the development board to be used in the IoT project; that is, the user already has all the technology background and the only thing needed is to know how to connect the IoT devices to the cloud

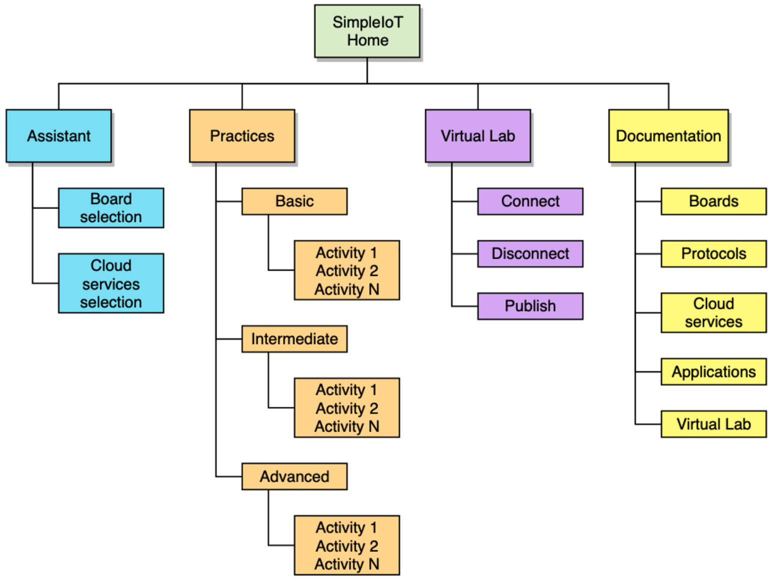

Figure 2: SimpleIoT educational platform distribution

Table 1: IoT practice types used in the Educational Platform

Practice type		Board use	Connectivity	IoT Platform	App development	Other characteristics
Basic	**No ICT**	None (all is simulated)	Wi-Fi, using the PC	Ubidots, Losant	None (all is displayed in IoT platforms)	None
	ICT	Arduino based	Wi-Fi, Bluetooth	Ubidots, Losant	None (all is displayed in IoT platforms)	None
Intermediate		Arduino based	Wi-Fi, Bluetooth, SigFox, LoRaWan	Ubidots, Losant, AWS (basic), Microsoft Azure (basic), IBM Watson (basic)	Android apps	Databases
Advanced		Arduino based, Pycom, Raspberry Pi 3/4, Special boards	Wi-Fi, SigFox, LoRaWan, Cellular (4G/5G)	AWS (advanced), Microsoft Azure (advanced), IBM Watson (advanced)	Android apps, iOS apps, Web based apps	Databases, advanced processing, analytics and Artificial Intelligence

services. This modality is aimed at experts or people who already know how to use the IoT development boards.

2.2.2 Practices. In this section, there are various practices on IoT systems that the user can fulfill to learn more about the IoT technologies. Within it, the content of the practices can be filtered by means of tags. One of the tags used is the difficulty level of the practice. Table 1 summarizes the characteristics of the selected elements depending on the level of complexity: Basic, intermediate or advanced.

2.2.3 Virtual Lab. Through the virtual laboratory, an MQTT (Message Queuing Telemetry Transport) client is used, where the user can subscribe to topics and post information to a remote broker. In this way, physical devices and connections to IoT services are managed from the user's computer without installing any additional software.

2.2.4 Documentation. In this section, the user can obtain more information about the technologies used in the web platform. It contains brief descriptions of the technologies (IoT devices, cloud services, communication protocols and end devices) and the tools available on the web platform.

3 APPLICATION CASE

The web platform can be used in different scenarios as shown in figure 3. In a course related to IoT, a teacher can ask the students to use it to carry out some didactic practices, or as support to develop a functional IoT project for the course. Another scenario is when

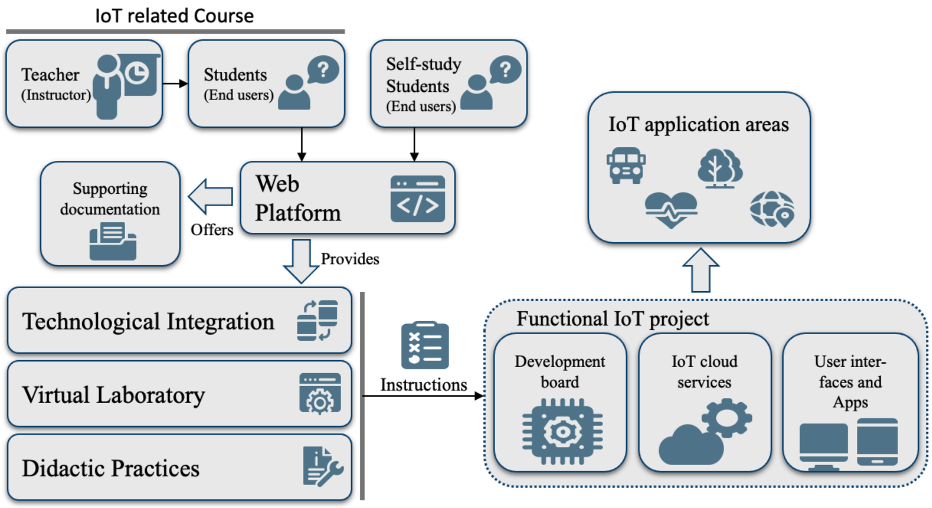

Figure 3: Different scenarios of how to use the web platform

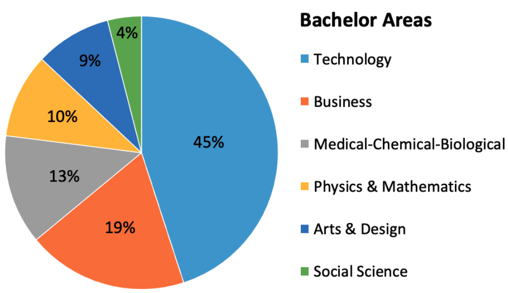

Figure 4: Number of students per bachelor area

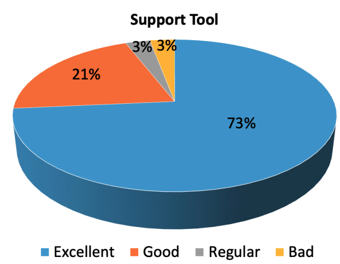

Figure 5: Evaluation of the platform as a support tool

a self-study student uses it as a tool to implement an IoT project of his interest. The platform provides students with supporting documentation, technological integration, a virtual laboratory to connect physical devices to the cloud, as well as didactic practices that, through an assistant, facilitates them to learn IoT concepts and to develop IoT projects.

The application case of this platform was accomplished as an elective topic for sophomore students of any degree. This course entitled "Discovering the IoT and its applications" belongs to the exploration stage where students can select different current topics to complement their studies.

The course lasted 60 hours in 5 weeks distributed in 5 modules: Introduction to IoT, Things that can be connected to the Internet, Things generate data and information, Things and the digital company and the implementation of a solution based on IoT for smart environments. The course was offered in fall 2020 amid the COVID-19 pandemic, so it had to be delivered remotely online. Modules 1 to 4 were taught by 3 teachers while the last one was total immersion of the students in the last week of the course. 102 students were enrolled from the areas shown in figure 4

For this course, the IoT learning platform with a basic level practice was used as an application case. The students registered on the platform, selected the practice and the instructions guided them step by step.

The objective was to link a *Losant* device to the virtual laboratory to send information from a simulated temperature sensor, which activates an alert when a specific value is exceeded, receiving a message on a mobile device. The students each fulfill this practice individually, to later work in teams of 5 students to design and develop a first prototype that provides a new solution to a global and local social problem. Teams were made with at least one female student (only 30% of the students were women) and with 2 students of non-ICT bachelor areas.

The practice begins with the configuration of the *Losant* dashboard for the visualization of the variables. A blank application is created, and the students are guided to register the devices, attributes and workflow. Subsequently, the virtual laboratory is used to generate and send the humidity and temperature data (simulation of sensors and readings for *Losant*), to finally visualize the data in the generated dashboard.

4 RESULTS AND DISCUSSION

At the end of the practice, an assessment of the utility of the tool was requested from the students who participated. The results indicate

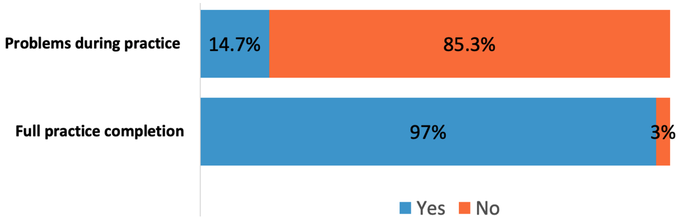

Figure 6: Practice completion and problems

that 94% of them find the platform as a good to excellent helper tool for learning IoT, as shown in Figure 5

Also, the students were asked if they completed the full practice and if they experienced any kind of problem during the practice. Results are shown in figure 6. The main problems that they experienced were data not updated and token problems.

The results about the relevance of the content information are shown in figure 7(a) with 82% in the two highest levels, and the results about if the students think it could be applicable in their future is shown in figure 7(b) with 76% in the two highest levels.

The IoT platform was robust and useful for this massive course. The students found this kind of platform useful to have a better understanding of the technology and make them more confident in their skills for making projects in their future. Some comments from the students about the technology were that they want more practices and programming for this course, suggesting as future work the availability in the platform of different leveled practices for the students that have some knowledge and want to take it further. The teachers of other modules on the topic found the platform a useful tool to teach it. As well, it serves to encourage students to experiment with technology, and suggest improving the user interface. They also recommend that it is necessary to reinforce the pedagogical side, to improve the monitoring of the use of the platform by the students, as well as the documentation of results online. This is to know the impact that is being had with the users and obtain feedback on the use of the tools and practices. Additionally, they suggest leaving one or a few free practices for many users to try as well as make more recommendations.

5 CONCLUSIONS

This article describes the development and implementation of a web platform as a support tool for learning IoT. The results obtained from its use in a group of approximately 100 undergraduate students indicate that the web platform is a useful tool, in the opinion of 94% of those surveyed, as a practical complement to courses aimed at teaching this emerging technology, both for related students and not related to ICT. The information on IoT present on the platform was considered highly relevant, 82%, in the opinion of the students. In addition, 76% of the respondents believe that after navigating the platform, as well as carrying out some practices present in it, allowed them to see areas of opportunity for IoT technology in the future that can be applied in different areas of knowledge. This first version of the platform still needs to validate its usefulness in different groups of ICT students for different levels of professional education. One area of opportunity being contemplated is using *SimpleIoT* for high school seniors interested in STEM areas. Given the dynamism of IoT, the platform was designed in a flexible way to adapt to the necessary changes in this technological evolution, both in content, number and complexity of practices, types of technologies and IoT platforms present in the market.

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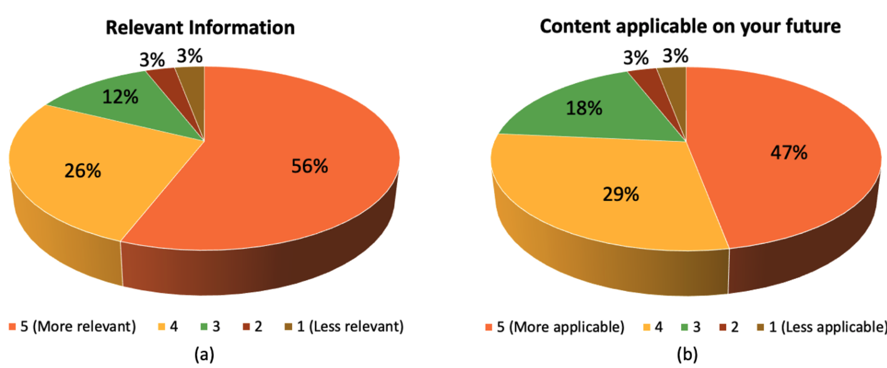

Figure 7: (a) Relevance of information in the practice, (b) Content applicability in the future

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