LMS (Learning Management System) Applying MQTT-IOT Networks and smart cities

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Abstract. Practical experience and theoretical study are the basis for solid technical knowledge. Electrical engineering courses require a series of laboratory exercises, often held in university facilities where students can practice only a few hours a week, if at all. This technique has changed dramatically after the Covid-19 health pandemic and social distancing. The possibility of acquiring and improving computational thinking and IoT technological development skills (MQTT) has been facilitated by new freely available digital tools, which has made it possible to go much deeper into the subject ("Smart Cities") in a didactic way. As a result, we propose systematically creating e-Learning distance learning workshops in a virtualized environment, including IoT simulators (sensors and actuators) interacting with cloud servers. Its implementation capability transforms the instructor into a facilitator or guide to acquire information and verify learning outcomes through checklists.

Keywords: MQTT (Message Queue Telemetry Transport), IoT (Internet of things), Sensors, Actuators, Didactics, Smart Cities, Social distancing, virtualized environment, Covid 19.

1 Introduction

The coronavirus disease pandemic (COVID-19) has caused an unprecedented crisis in all fields and all countries. It is not an isolated event in education, as teaching and learn-

ing methods are gradually being transformed. In addition, the massification of the Internet has forced the educational community to ensure that students have equal opportunities to access technologies. However, it has been necessary to accelerate the innovation process and incorporation of digital tools based on totally virtual environments to continue developing classes and transmitting learning at a distance. Under the disruption of face-to-face courses, teachers in technology and innovation have needed to maintain the continuity and intensity of technological laboratories. They have imposed new challenges that have been taken through connectivity and a virtual context, non-face-to-face means, and a progressive adaptation[1]. The article proposes establishing a methodology and scenario in a virtual environment to develop computational thinking. A development of competencies related to the creation of IoT technology based on extensions ('Sensors and actuators') simulated in interaction with the cloud through the MQTT protocol, in this case, real platforms open for the registration of censored information. The implementation of virtual simulators helps to create and promote learning environments where students corroborate their theoretical knowledge through technological tools without the need to be in a physical laboratory[2]. A curricular transformation due to the pandemic in terms of those laboratory practices carried out with electronic components or extensions in the institution's premises.
The article consists of the following sections: Section 2 defines a context of current technologies to define education in a virtualized context; here, a bibliometric analysis is established to determine how technological areas influence education and to know future trends. Section 3 describes the main technical components for creating IoT technology connected to the cloud in a virtualized context. Section 4 shows how this technology architecture works and how to record learning evidence for assessing technological competencies. The work's main contribution is based on defining a framework through virtual tools to develop projects oriented to the design of IoT architects on the web in the engineering area.

2 State of work

the efficient integration of technology and education becomes a paramount necessity in a world connected by the Internet. The challenge of education in a period of social isolation has leveraged a development potential, not only from the point of view of innovation but also from the pedagogical and transversal point of view between the different subjects. This integration between these various components is essential for curricular progress, and the generation of new knowledge is highlighted. New trends in virtualized contexts, such as e-learning and STEAM methodology, are introducing new teaching schemes and a dynamic knowledge construction process. The teacher is redefined more as a collaborator and technologically oriented to achieve the goals proposed in education[3,4]. A constructivist approach should be established as an active component of STEAM since it stimulates the meaningful construction of knowledge, i.e., deep learning, among the different actors of education. For its part, the holistic approach defines people with complex thinking. It is mainly intended to remedy the shortcomings of traditional teaching through discovery learning, Bloom's taxonomy, instructional learning, humanistic learning, and dimensions of learning. Likewise, although each component can install its theory, the maintained premise is to focus on learning based on the student's experiences of learning based on problems of reality, connecting with thinking, and discovering. For this reason, it is necessary to reiterate an approach that privileges transforming and integrating skills from different areas of knowledge, from engineering to mathematics, while the social skills to solve problems are materialized in the dynamics that encourage the training of students so that they manifest attitudes, have the necessary knowledge to mitigate problems or provide solutions through the analysis of evidence, integrating collective efforts with planning teams. Additionally, the current development of this new significant experience is possible thanks to the increase in Internet bandwidth and the creation of technological infrastructure that allows bringing the Internet to be remote and difficult-to-access areas. There is also the consideration of other necessary specialized components related to web architecture, which have been evolving in favor of the development of new services oriented to education and virtual environments; among these, we have:

- Homogeneous storage of information.
- Reduction of infrastructure costs
- A single data structure, as well as communication protocols.
- Use of metadata.
- Development of open source learning platforms LMS (Learning Management System) for educational environments ("Moodle, Virtual U, Top-class").
- Easy implementation of new IoT simulators compatible with web 2.0.
- Emergence of new messaging tools ('Wassup, telegram, etc.') and video conferencing ('Google Meet, zoom, etc.') compatible with mobile devices.

All these components have allowed a web-centered learning environment to transform from a passive element to a virtual ecosystem where it can interact dynamically, carry out semi-personalized tutorials between the student and the instructor or clarify doubts in real time. Additionally, the recognition of converging technologies contributes to the growth of e-Learning to improve the virtual educational process, which must be efficient. To help recognize this set of technological trends that have influenced education directly or indirectly, we have developed a bibliometric analysis in Figure 1, which illustrates the latest technological trends and those directly related to educational environments.

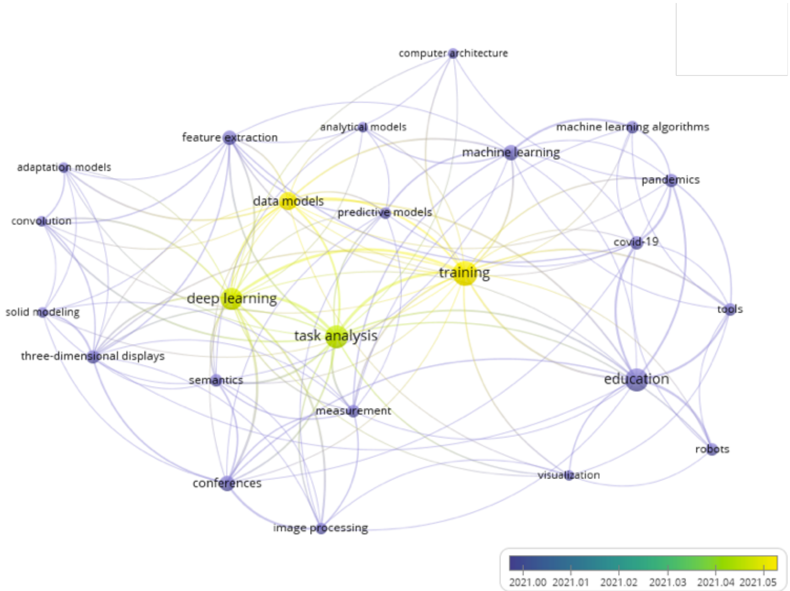

Fig. 1. Bibliometric analysis fed through 54,609 related documents, among those selected: Conferences (44,920), Journals (7,708), Magazines (925), Early Access Articles (826), Books (202), Standards (21). all with the theme of Virtual Learning education, extracted from the IEEE.explorer scientific database and analyzed with the VOSviewer_1.6 tool.

As determined in the bibliometric study, the technological trends or topics that present a higher correlation in educational research are Robots, visualization, tools, covid.19 other trends stand out as future trends to evolve and change in the future concept of education: Robots, visualization, tools, covid19. Other trends are highlighted as future trends to grow and change in the future idea of education: Training, task analytics, data models, predictive models, and Deep learning, which are directly related to the development of computational thinking. The proposal can be pigeonholed within tool development and training trends for all of the above: the virtual learning environment, tools, and cloud connectivity[5,6]. The proposed architecture is based on virtual IoT simulators under the Raspberry pi 3 tool and its Noobs operating system, virtualized through Virtual Box. As they are software that requires low processing power, since they consume low energy due to the demands and the nature of the IoT system, it is possible to run these tools on a low-end computer processing, for the study was developed on a computer with 4GB in RAM, and a hard drive of 40 GB, where it is installed as host operating system Ubuntu. The IoT operating system to be installed can be downloaded at: https://www.raspberrypi.org/software/, which has the IoT HAT sense simulator, as shown in Figure 2. The HAT Sense has a set of environmental sensors to detect environmental conditions; it can measure pressure, temperature, and humidity through a programming code based on the Python language. The activities to be developed are focused on assembling technological components that interact between simulators to send sensed information to the cloud. Each action is governed by a learning guide previously defined and clarified in its technical language, then the IoT simulators are instantiated, as shown in Figure 2.

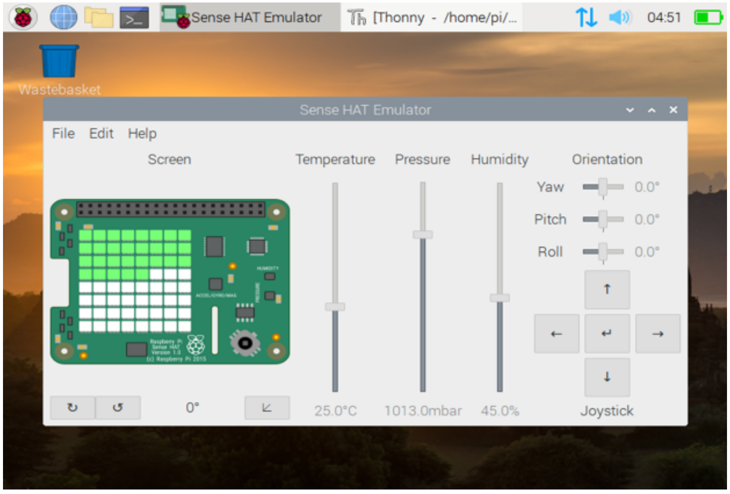

Fig. 2. Sense HAT Emulator: Contains virtual simulators that act as sensors for data capture. Additionally, it has a display for alphanumeric character output.

Thanks to its low implementation difficulty, it is possible to census and send data to the cloud by implementing native libraries, and API (Application Programming Interface) routines of the system adapted to the platform's hardware, as illustrated in Figure 3.

A cloud service established by Adafruit.io offers the API; that is, it runs on the web and defines a range of components necessary to collect sensor data on each IoT device. These components are mainly designed to store and then retrieve data in real-time. In other words, online, it is possible to connect motors, read data from sensors, and connect them with other services on the web, such as Facebook, Gmail, Twitter, and RSS feeds.

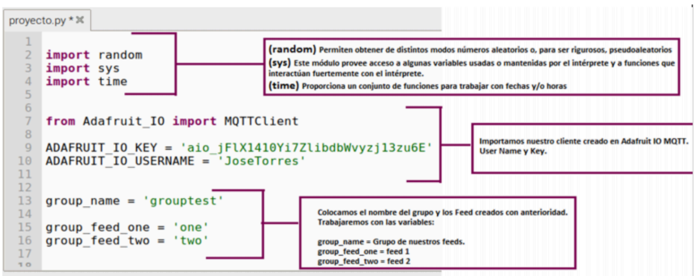

Fig. 3. The HTTP (Hypertext Transfer Protocol) API of Adafruit IO and the MQTT client library allows an authentication process to send information to the cloud; this data can be processed directly through the server boards called Feed; in this case, two feeds have been instantiated for recording information on the web (one and two), one for pressure and one for temperature.

Each data sent to the cloud directly relates to a system feed or dashboard. This configuration allows graphing the data obtained from each Sense Hat terminal from the web. In other words, each value recorded from each IoT device through its sensors is sent in real-time, stored, and plotted from a dashboard on the Web. Finally, we can consult the recorded values through configurable graphs, as shown in Figure 4.

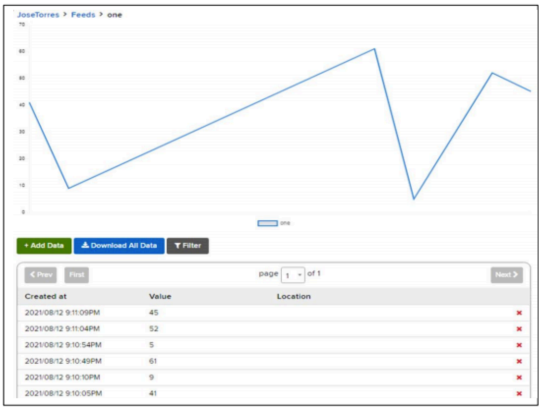

Fig. 4. Data that can be consulted in the "one" dashboard from any device that can connect to the Web, with prior authentication from the server.

This data dashboard allows us to evidence learning competencies since if monitoring data is recorded, it is the product of an efficient connection. With this data logging through IoT devices, we can analyze the data, detect possible problems, and find the actions we can take to solve them as learning guides.

3 Technological architecture and learning registry.

The main contribution is implementing servers with dedicated inputs to MQTT from the web, the popular protocol for developing IoT architectures, through simulators running in browsers. One of the primary keys to MQTT communication is the Broker, the program responsible for receiving client messages and distributing them to each other in a pub-sub system. MQTT is a lightweight publish/subscribe messaging protocol designed for telemetry in low-bandwidth environments, allowing it to be deployed from hard-to-reach locations. For this reason, MQTT is rapidly becoming one of the leading protocols for IoT deployments. This protocol contains two main components: The Broker, which is the server that distributes information to interested clients connected to the server, and the Client or device that connects to the broker to send or receive information, as illustrated in Figure 5[7].

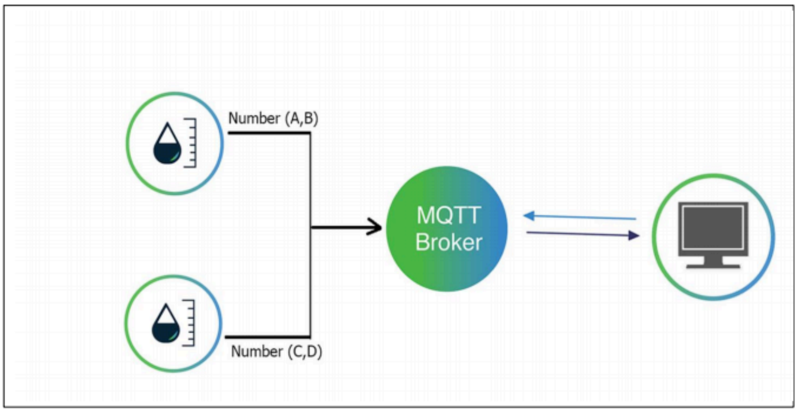

Fig. 5. Each IoT device can send data simultaneously to the broker. This data is recorded for later retrieval.

The definition of these technological tools that are easy to implement and open to the academic community is essential for the progress of education in a virtualized context. Still, their effectiveness depends on the teacher, how they use the didactic strategies, and the registration of each activity and competence through checklists, as illustrated in Figure 6. This conceptual model originates a dynamic process in cooperative learning, using simple language for the participants and clarifying some technical concepts beforehand so that the interaction is fluid to meet each technological guide's teaching and learning objectives.

Step	**Item**	**R**	**NR**	**observations**	**recommendations**
Programmed and configured tool.					
Sending data to the cloud					
Server configuration					
API registration					
Sensor configuration					
Programming through python					
Address configuration					

Fig. 6. Checklist for IoT technology development.

Finally, to determine whether the methodology was efficient in quantitative terms, an analysis of variance was defined through the ANOVA technique, which shows that those students who had virtual practices improved their academic performance. The article details the numerical results of the model and corroborates the hypothesis that this virtualized environment is efficient for developing technological competencies.

4 Analysis of results – ANOVA (Analysis of Variance).

To examine the results and see if this methodology significantly increases the understanding of IoT concepts, two knowledge tests are carried out, one before applying the method, a pretest test, and another test after a posttest. For this, a field study was carried out for two engineering courses of 40 students each, where course one did not apply this methodology, and course two did apply it with tools and virtual simulators. We proceed to establish a hypothesis of the researcher, where it is shown that the new results verify a significant increase in technological knowledge[8].

Null hypothesis Ho: There are no significant differences in their means concerning the test results.

Researcher's hypothesis H1: There are significant differences in their means for the test results.

To process the data, they must comply with the assumptions of normality and homoscedasticity in the variance.
Note: The data were obtained from an analysis of variance; the data must comply with the assumptions of random sampling, normality, and homoscedasticity of variance. It proceeds to find its descriptive statistics and ANOVA through the SPSS (Powerful Statistical Software Platform) software. See figure 7.

ANOVA explores the idea that the means of two or more populations are equal. ANOVAs evaluate the means of the response variable at different factor levels to identify the significance of one or more factors. The null hypothesis asserts that all population means (factor level means) are equal, but the alternative hypothesis asserts that at least one differs.

To run an ANOVA, you must have a continuous response variable and at least one categorical factor with two or more levels. ANOVA analyses demand data from populations with an approximately normal distribution with similar variances across factor levels. However, unless one or more distributions are significantly skewed or the variances are quite different, ANOVA procedures function fairly well even when the assumption of normality is violated. These violations can be corrected through transformations of the original data collection.

I.	N	Mean	Desv Stan	Desv Err	Limit lower	Limit Upper	Min	Max
1	40	3,249	0,54	0,086	3,31	3,66	2,3	4,7
2	40	4,04	0,56	0,089	3,86	4,22	2,5	5,1
Total	80	3,7	0,62	0,062	3,62	3,9	2,3	5,1

II.	Sum of squares	gl	Mean square	F	Sig
Intra groups	6,16	1	6,16	19,73	0
Inter groups	24,355	78	0,312		
Total	30,515	79			

Fig 7. I Descriptive statistical data II. ANOVA, Analysis of variance and descriptive statistics.

We see that the posttest group has a mean of 4.0 and the pretest group has a mean of 3.4, which are significantly different since, according to the result of the ANOVA p-value, it is 0.00<0.05, which leads to rejecting the null hypothesis. The null hypothesis defines that there is no difference between the means of the results of these groups. See figure 8.

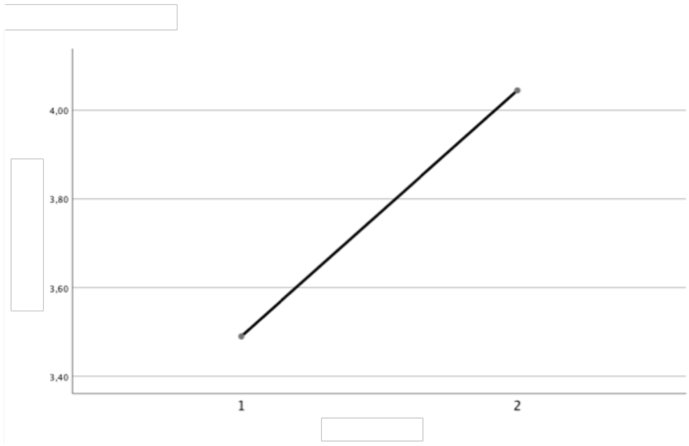

Fig 8. Graph of means Vs. groups 1 and 2.

6. Developing Formative Evaluation of the Learning Environment

The proposed platform can be defined as a strategic and systematic evaluation to maintain a solid knowledge of IoT architectures in a distributed environment such as smart cities. A dynamic and formative assessment stands out, where the instructors or teachers provide constant and continuous feedback to monitor the performance and learning progress of the students during the teaching period. For efficient control, it is necessary to conduct brief evaluations at the end of each module or invite advanced students to serve as mentors by contributing their opinions to the learning and teaching activities. This set of approaches supported by an e-learning platform offers proactive solutions to improve the learning environment. Each teaching and assessment module are programmable, and short assessments can be distributed between sections. These tools will help teachers make timely adjustments to their teaching and maintain a quality learning environment by identifying and addressing concerns about the learning environment.

7. Conclusion

The teaching and learning processes are effective and progressive, with constant discovery. The article provides the design of an LMS platform to create and maintain a blended and online learning environment for teaching IoT architecture through virtual tools. That allows actuators and sensors to be modeled through Python programming for a distributed environment. Through this study, it is revealed that the learning methodology has a significant effect on teaching technological concepts since, through an analysis of variance, a positive and significant impact is verified by improving the teaching process in the classroom. Additionally, it was evidenced that students are more committed to developing online content. They are motivated by the platform's flexibility when creating dynamic and distributed scenarios, such as smart cities, precision agriculture, and intelligent parking lots. For to ensure the efficiency of their teaching, the teacher's presence is required as a facilitator guide to provide opportunities, explore the agreement and disagreement of the topic of the subject, provide timely direct instruction, encouragement, and feedback, and constantly make timely adjustments by conducting formative assessment in learning activities.

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