Teaching CT through Internet of Things in High School: Possibilities and Reflections

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***Abstract*—This Research to Practice Full Paper presents a pedagogical practice for technical high school students for developing Computational Thinking (CT) abilities through Internet of Things technologies. The covered topics in our proposal include (i) the use of temperature and humidity sensors for data collection, treatment and visualization using Arduino and micro-controllers; (ii) Smart and Human Cities (SHC) and Open Data concepts, in order to lead the students to reflect on the problems of their city and on data protection. Our motivation to our proposal is due to the educational processes have to develop criticality and the ability to solve problems among students. In this context, CT has been used for this through the use of robotics, game building or unplugged computing. On the other hand, technologies for implementing Internet of Things (IoT) have been used in several domains of society, including cities transformation. One important aspect in this scenario is data generation, which have to be carefully tackled by government's and who develop solutions to SHC. In this way, using IoT for teaching CT is an important aspect, also considering open data, privacy and SHC context. In our pedagogical practice, students were able to design and develop solutions to problems in their daily lives indirectly applying CT skills, such as decomposition, pattern recognition, abstraction, automation and analysis, as well as self-skills, collaboration, creativity and critically, required nowadays in broad professional training. It was also possible to develop students' interest in raising awareness of the use of computational technologies, as a solution to problems in society considering aspects of SHC and open data; propose a technological solution using IoT; and analyze the use of these data collected for the social well-being. For the evaluation of our proposal, we carried out questionnaires and tasks observation. The experience was considered successful in its planning and application, with a positive evaluation of the participating students.**

***Index Terms*—computational thinking, internet of things, programming teaching, smart and human cities.**

I. Introduction

Information and Communication Technologies (ICT) are inserted in the daily lives of most people. However, using technology is not limited only to knowing how to surf the internet, sending an e-mail, publishing a blog or operating a word processor. There are aspects of social change, processes and innovation through which several areas have made significant contributions through the use of technologies [1]. In Education, for example, several digital solutions have emerged, either to aid in educational management processes or for pedagogical use. It is essential that students use technologies as tools that enable them to solve problems and, thus, generate new knowledge. This ability to use Computer Science principles to develop competencies and skills for analyzing and solving problems is called Computational Thinking (CT), a construct in development in the last decades [1]. This term was firstly presented by Wing [2], although Papert firstly introduced the ideas [3]. According to Wing, CT is the ability to use fundamental concepts of Computer Science to solve problems in the most diverse knowledge areas, considering reality and socioeconomic context of the students, motivating them to look for solutions to everyday problems. In this context, many researches are being conducted in several countries in order to insert the concepts of computing in basic education levels, involving the use and proposal of unplugged computing technologies [4], algorithms and programming [5], learning objects [6], [7], game design & development [8] and robotics [9].

On the other hand, with the advance of microelectronics, embedded systems and computer networks, in the last decades emerged the concept Internet of Things (IoT) [10]. IoT aims to connect objects to the Internet and promote communication between users and devices. New applications emerged with the advance and reduced costs of IoT technologies, including micro-controllers, sensors, actuators and other electronic components, specially in Smart and Human Cities (SHC) and Ambient Intelligence development. In this context, IoT is an area of study that has theoretical, practical and social challenges, due to not only allowing several applications development in SHC but also demanding responsibility to the developers to guarantee aggregated public value in these solutions and privacy in collected data.

In this research we consider three main aspects for our proposal: (i) the development of skills and competences for the 21st century, involving communication, collaboration, critical thinking, creativity and the ability to solve real life problems [11], aligned to CT purposes; (ii) the possibility of using IoT for developing applications in SHC and Ambient Intelligence scenarios; and (iii) the requirement of raising responsibility on the collected data bu the developers. We firstly looked for works in literature that explore how IoT is used for teaching and developing CT skills. After, we propose a pedagogical practice for teaching CT skills through the use of

IoT technologies considering Ambient Intelligence, SHC, Data Privacy and Open Data concepts. To this end, we developed tasks for the students, and questionnaires for evaluating our experiment results.

II. Background

This section briefly presents the main concepts of the areas covered in the developed pedagogical practice.

A. Computational Thinking

CT idea, although not called with this name, was presented by Papert [3], who argued that the appropriation of technological tools by children provides to them a rich framework to create new knowledge through problem solving using Computer Science concepts. Wing [2] presented this term in 2006, who states that CT is the ability to use fundamental concepts of Computer Science to solve problems in the most diverse areas of knowledge. CT assists in formulating problems and solutions represented in a way that can be executed by information processors, humans, computers or, even better, by a combination of both. Analyzing the works of Wing [2], [12], we observed that CT can be decomposed into five main abilities, which we used in this work: (i) Abstraction: the ability to ignore some details in a solution so that it can be valid for different problems, and the ability to understand abstractions necessary for processing data and building solutions through algorithms, i.e., the ability to stipulate an order or sequence of steps to solve the problem; (ii) Automation: The ability to automate solutions, allowing machines to help us solve problems; (iii) Analysis: The ability to use techniques for analyzing algorithms in terms of their correction and efficiency, under different aspects; (iv) Decomposition: the ability to divide the original problem into smaller and easier problems; and (v) Pattern Recognition: the ability to identify patterns among different problems.

Several studies have been carried out throughout the world with the intention of inserting the CT in primary and secondary educational levels [6], [13]. Alternative ways for teaching CT include teaching Unplugged Computing, which aims to insert the concepts of Computer Science without the aid of computational technologies [4]; teaching programming [5], [6]; creating learning objects [6], [7]; developing games [8] and teaching robotics programming [9]. Also, Nascimento, Santos and Tanzi [14] presented a Systematic Literature Review analyzing the interrelation between CT and interdisciplinarity in primary and secondary education, which was also preliminary discussed by Wing [12]. According to the authors, there are still few works that explore CT in an interdisciplinary way, and most of these studies are carried out only in math and science projects and courses. Ortiz and Pereira [15] presents the possibility to teaching CT in Youth and Adult Education. According to them, the public in question, in addition to acquiring the skills, have the chance to update themselves about the available technologies and thus train themselves for the society increasingly interconnected by technology. In this way, teaching CT can be approached through different techniques and contexts. Though, there is a diversity of possibilities that need to be explored, such as through IoT, considering Ambient Intelligence, SHC and Open Data Concepts.

B. Internet of Things

According to Coetzee and Eksteen [16], IoT is related to connecting objects, such as water and air quality sensors, vehicle and person traffic sensors and video cameras, in the internet. In this way, these objects must be identified in the internet; their location and state must be known by the applications; and they must be connected in the internet to be accessible through an interoperable network. In addition, they can control and be controlled remotely. The evolution of technology and the consequent lower cost of sensors and actuators have made IoT technologies applicable for developing environments through Ambient Intelligence (Aml) technologies, such as cities, houses, hospitals, gardens and industry, in the recent movement called Industry 4.0. These applications include monitoring environmental variables to alert and prevent floods and fires; monitoring vehicle and people traffic. In this context, IoT brings technologies that has an impact on all segments of society such as health, education, public security and urban mobility. Despite the significant increase in the storage, processing and data transmission capacity of IoT devices, there are still major challenges in a theoretical, practical and social scope, including teaching these concepts in higher education [17]. So, teaching IoT technologies, concepts and practices allow students to envision new opportunities, whether in developing solutions or pursuing a career in computing, mathematics and engineering areas.

C. Ambient Intelligence and Smart and Human Cities

According to Cook [18], Aml is an emerging area, aiming to provide intelligence in daily environments. Aml researches are based on advances in sensor networks, pervasive and ubiquitous computing and artificial intelligence. Aml have been applied to develop cities, which originated the term SHC, involving the use of sensors for improving life quality to citizens [19]. However, in more recent works, there is an effort to pay attention in how to create public value in urban spaces [20]. The Brazilian Network of SHC state that cities must "sustain their own continuous evolution, having as goals the well-being, the quality of life and the empowerment of the citizen and the local communities, supporting their development in actions, projects and public policies that promote (in an egalitarian way) collaboration between community, public authorities and civil society for mediation and conflict resolution, as well as promotion of local creativity. These cities use advanced social interaction technologies and a resilient, interoperable and transparent technological infrastructure for the generation and management of data in an open and accessible way and in constant improvement and evolution, which allows improving, increasing and automating the functions of the city in an efficient, integrated, sustainable and relevant way for the population" [21]. In this scenario, it is essential in

SHC that citizens participate in the strategic management of the municipality, whether in the development of innovation in technology and/or processes for public management or for private initiative. Furthermore, it is essential that this participation is based on the use of public data. In this way, the citizen will be able to use the information obtained to demand improvements in education, health and public safety. For this purpose, it is necessary to have educational practices to develop competence skills to search, understand, analyze and use public data.

D. Open Data and Data Privacy

Eaves [22] states that, for a data to be considered open it is necessary to follow three rules: (i) if the data cannot be found and indexed on the Web, it does not exist; (ii) if it is not open and available in a machine-understandable format, it cannot be reused; and (iii) if a legal device does not allow its replication, it is not useful. Several countries around the world, including Brazil, proposed initiatives to regulate access to government data, usually available in open government data portals [23]. Also, General Data Protection Rules were presented by United Nations to discuss data privacy aspects. These aspects emerge the importance of considering dopen data and data privacy concepts and aspects in pedagogical practices.

III. Literature Review

Improving the quality and effectiveness of education in diverse areas using computational technologies has been a common point among researchers. In this way, researches using technologies such as Ubiquitous Computing, Mobile Computing and IoT in educational context have been developed. For example, Magdalinou and Papadakis [24] present an experience report on the application of a pedagogical proposal for teaching ubiquitous computing, mobile computing and IoT targeting high school students. The authors identified that, with the participation in classes, the students felt motivated and interested in choosing professional careers in technology and engineering. According to the authors, the biggest challenge was to develop ways to use the technical characteristics of technologies to lead to learning, and not just to lead to information access by the students.

Viberg and Mavroudi [11] analyzed the responses of ten experts on the success factors and challenges of ubiquitous computing and IoT in the skills and competencies development by the students in the 21st century. According to the experts, students are able to develop through CT both social and ethical skills, including communication, collaboration, critical thinking, creativity and self-regulation. The success of the use of these technologies in classroom depends on the interest of the students. In other words, it depends on the motivation to use the knowledge of the technological resources to solve everyday problems. Another success factor is due to the robustness, usability and maturity of the used technology. The listed challenges are related to the scalability of using the technology in the classroom due to financial costs.

Another way for developing new skills is implementing laboratory makers or fablabs in primary, secondary and higher education, according to Eriksson *et al.* [25]. These spaces or laboratories aim to provide collaborative and creative work using IoT concepts, electronics and programming, in order to develop (i) PC skills in students; (ii) motivation and interest in science and technology in students; (iii) students' ability to relate media and information in a more critical and responsible way; and (iv) to inspire creative ways of solving problems. The authors pointed out that the challenge for implementing fablabs in schools is to develop (i) curricular strategies with a didactic sequence; (ii) teaching materials; (iii) methods and activities that can not only be easily integrated but also be flexible to support differences in the school context; and (iv) deadlines and different levels of learning. These characteristics turn the strategy to construct and implement a fablab not so trivial.

Lensing and Friedhoff [26] present an experience of a curriculum adaptable to different audiences such as children, students, researchers and entrepreneurs, to be developed in fablabs. They use IoT programming and concepts in order to develop skills and competences in engineering students so that they are qualified to Industry 4.0. The developed skills were creativity, new problem solving and PC skills. This is due to fablabs being environments in which learning is self-regulated, knowledge acquisition does not necessarily need a hierarchy ,and its focus is on solving a real world problems. Also, cooperation and knowledge exchange in interdisciplinary contexts are also present in these labs.

In this way, we could observe that researchers have dedicated to developing pedagogical practices in order to insert the teaching of technologies, among them IoT. in different levels of education. Their objectives are mainly using concepts of IoT, electronics and programming to develop PC skills, as well as to motivate and increase interest in students to choose professional careers in technology and engineering. Also, the success of using these technologies in classrooms depends on the engagement of the students, as acquiring new knowledge does not necessarily need a hierarchy. Also, cooperation between students is needed for exchanging knowledge in interdisciplinary contexts. Thus, pedagogical proposals developed for the teaching of IoT should be motivating and meaningful. For this, scenarios from real world to students. So, they should develop solutions to real problems of their daily lives, relating to areas such as health, agriculture, SHC and so on. The proposals should also be developed with teaching materials, methods and contents that can be easily integrated and flexible to support differences in the school context, deadlines and different levels of learning so that it is not trivial or too difficult.

IV. Educational Practice with IoT: A Proposal

In this study we use the context of SHC and Humanities for teaching CT through IoT. We aim with our practice that students are able to develop CT skills through the development of innovative solutions for SHC using IoT technologies. We consider citizen participation in public management as well as ethical, privacy, integrity and information access and personal data protection issues regarding the data collected, transmitted and stored.

We present a proposal of educational practice composed by activities gathered in a workshop format, with a total workload of 20 hours. The workshop was organized in 7 (seven) sequential activities. Six activities were in meeting in classes format, destined to the explanation of contents and practices realization. One activity (Activity 6) was to the students to work on their own in their solution projects. In the last activity (Activity 7, a meeting in class), the students presented their works to the class and guests. Also in this class, a post-questionnaire was applied with the purpose of collecting data about the students' perception about the Workshop. Our proposal addressed three major areas: IoT, SHC and public data. The activities were planned so that the students had contact with the contents in an incremental way, *i.e.*. the students were acquiring new knowledge about the three big areas in each activity. To understand the motivations, behaviors, needs and adequacy of the educational practice proposal to the target audience, we conducted a qualitative assessment on the data collected in the Pre- and Post-questionnaires and on the observations of the professor (also the first researcher in this work). In what follows, we detail the planning of each activity, presenting (i) content and activities; (ii) workload; and (iii) CT skills to be developed.

- **Activity 1**: (i) Explanatory content about SHC and IoT concepts: Presentation, workshop objectives, IoT concepts, SHC and Pre-questionnaire application. (ii) 4 hours. (iii) CT skills: decomposition and pattern recognition.
- **Activity 2**: (i) Explanatory content about Public Data: Integrity, privacy, access and protection of data and its ethical and legal aspects. Law of Access to Information and General Law of Protection of Personal Data. Citizen, government and technology. (ii) 4 hours. (iii) CT skills: decomposition and recognition of standards.
- **Activity 3**: (i) Explanatory content about IoT in practice basic concepts: Basic electronics, sensors, actuators, Arduino, Esp32 and programming notions. (ii) 4 hours. (iii) CT skills: decomposition and recognition of patterns abstraction, analysis, algorithms and automation.
- **Activity 4**: (i) Explanatory content about IoT in practice smart objects: Collect and visualize data with Arduino and ESP 32 through temperature and humidity sensors. (ii) 4 hours. (iii) CT skills: decomposition and recognition of patterns abstraction, analysis, algorithms and automation.
- **Activity 5**: (i) Explanatory content about IoT in practice given in clouds: Conceptualize the cloud architecture to save and access the data; know the site https://thingspeak.com/ and its functionalities; program the prototype to save and access the data in the cloud. (ii) 2 hours. (iii) CT skills: decomposition and recognition of patterns of abstraction, analysis, algorithms and automation.
- **Activity 6**: (i) Students working in groups on their proposal solution. (ii) 7 days. (iii) CT skills: decomposition and recognition of patterns abstraction, analysis, algorithms and automation; other skills: cooperation and collaboration.
- **Activity 7**: (i) Students presenting their solutions for SHC: Presentation of the Final Project and application of the Post-questionnaire. (ii) 4 hours. (iii) CT skills: decomposition and recognition of patterns abstraction, analysis, algorithms and automation.

The materials used in the activities were: Arduino Uno R3 Original; Wemos Esp32 lolin; Protoboard 400 holes, LEDs 3 mm various colors; Kit 400 resistors of various values; Kit Jumpers Cables 40 units; Switch PushButon 12x12x7 mm; Sensor Temperature and humidity DHT11. Arduino R3 Original and Wemos Esp32 lolin micro-controllers have inputs and outputs to receive and send data to sensors, actuators, screens, and many other devices, functions performed by programming them. The DHT11 temperature and humidity sensor was used to show the data collection, it was chosen because the data collected by it are of previous knowledge of the students. LEDs and Switches are components used to show the passage of current through the electronic circuit, resistors are used to limit the electrical current in a circuit. The protoboard and the jumpers cables are used to connect the electronic components (LEDs, switches, resistors and sensors) to the microcontroller in a functional electronic circuit. It is worth mentioning that the Arduino Uno R3 Original micro-controller needs an external module (shild) to connect to a WiFi network, whereas the Wemos Esp32 lolin micro-controller can connect to WiFi or Bluetooth without the aid of external modules, because connecting the micro-controller (things) to the Internet is an essential part of the Internet of Things concept.

Figure 1 presents a proposed electronic circuit in order to understand the contents, prototype, program and visualize the data collected by the DHT11 sensor to read ambient temperature and humidity, so that students understand that the sensors work as data collectors, that the variation in the collection time can be programmed, and also, that the data can be stored locally and/or in a cloud.

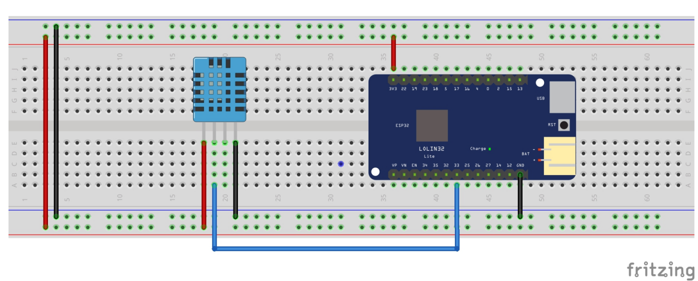

Fig. 1. Electronic circuit with DTH11 sensor

V. Results and Discussions

In this section we present the execution of the proposed practice as well as a discussion about the lessons learned. The implementation of the educational practice proposal took place at , Federal Institute of Education of Tocantins (IFTO) - Campus Colinas do Tocantins having as target audience students from the 1st year classes of the Computer Technician and the Agricultural Technical Courses, both integrated into high school. As the target audience had less than 18 years old, the students and their respective legal guardians signed the terms of participation consent. In addition, to ensure the anonymity of participants, we use the term "Respondent" in this work. Forty students participated in the workshop, being 23 from the Computer course and 17 from the Agricultural course. From these, 19 were female and 21 male. The age varied between 14 and 17 years.

The pre-questionnaire for diagnosis aimed to obtain information about the profile of students and their previous knowledge about the concepts of SHC, IoT, and public data. In relation to previous knowledge about SHC, IoT and open data, 31, 36 and 30 students respectively answered "Nothing", "I don't know" or "I've never heard of", thus showing that most students did not know the subjects to be discussed in the workshop. Questions were also asked to understand how students use the internet and what social networks are used. 33 students reported that Internet access is via mobile devices, and 7 access the Internet via computers, with the preference of students being smartphone use.

We asked if they were aware that the smartphone can record audio, get the location and take photos without the user's knowledge. 26 respondents (65%) said they knew this information, which is a high number. 20 respondents stated that they use 3 or more social networks; 12 respondents use at least two social networks; 7 respondents use only one social network; and only 1 said not to use social networks. The most used social networks are, respectively, Instagram, Facebook, Google+ and Twitter. Thus, we observed an intense use of social networks by respondents, with a view to 50% making use of at least three social networks.We also questioned the purpose of using social networks, and students could choose more than one answer option. 27 use to post photos of them and their family and friends; 26 to share memes; 6 to chat with virtual friends; 2 to chat with unknown people; and only 1 replied that it uses to share news.

We also asked what respondents knew about data protection on the smartphone and social networks. 6 students believe that the protection of personal data boils down to installing applications for this purpose; 5 understand that there is a need for data protection, but they argue that it is difficult to have a means to this end, and that this data can be accessed; 2 argued that the government can have unrestricted access to personal data; only 1 showed that social network information can be used by companies; and 17 other students replied "Nothing", "I don't know" or "I've never heard of", showing ignorance of information access and privacy laws.

We then began the implementation of educational practice activities. The students were organized in groups of 4 to 6 members, due to the amount of material available for the practices, we stipulated that the groups should be the same in all activities. In what follows, we describe the developed activities:

Activity 1: After presenting the concepts of SHC, IoT and open data, the students gathered in groups and should at the end present a project to help the city to be an Smart and Human City through the use of the Internet of Things. The students understood the proposal of the activity, there was a brainstorm stage and the students themselves came to the conclusion of what idea they would present at the end. We can see that the first group activity was quite successful, and the students were able to listen and explain about different ideas until they found the one they would work on. In this activity, decomposition skills were exercised, through the elaboration of the solution proposal, because it was decomposed into small problems, for the compound solution; pattern recognition was also exercised in the elaboration of the prototype, because the ideas presented were based on other solutions presented by the researcher during the activity.

Activity 2: After the presentation of Public Data contents, the students were guided to research data in public portals on the theme of the project defined in the previous activity. As presented in the analysis of the information collected in the pre-questionnaire, the students had no knowledge about the topics presented, and some students reported that they did not fully understand how to use the public data to obtain the information they were seeking. In this way, the topic can be better explored on the basis of practical projects to be carried out. In this activity, decomposition skills were exercised, through searching activity of data related to the quantity of beneficiaries of the municipal family scholarship; the recognition of standards was exercised in the search of data related to the salaries of federal, state and municipal employees who work in the city.

Activity 3: In this activity, the students had their first contact with IoT technologies, which included Arduino, ESP32, a prototype board, jumpers, LEDs and PushButon. The objective of the activity was to create an electronic circuit with a button that, when pressed, would turn on or off an LED. After the assembly of the physical prototype, the logical operation was presented, that is, the programming of the electronic circuit. The Arduino IDE development platform and its operation, as well as the main elements of the source code, were displayed. The students showed attention and excitement in the activity, and we observed that the students researched against themselves about electronics, Arduino, ESP32 and programming and were able to carry out the activity successfully. All members actively participated, however, some presented doubts about the syntax of the programming language spending, at some moments, a lot of time to find syntax errors. In this activity, decomposition skills were exercised, through the prototyping activity because each component is interconnected to the microcontroller by means of jumpers until the final prototype is available; pattern recognition was exercised; abstraction is exercised to understand the input, processing and output of the electrical signal in the microcontroller to be responsible for switching the LED on/off; analysis is exercised by understanding the specifications necessary for the prototype to function as it is: power supplies and software download to the microcontroller; algorithms are exercised in the sequence of commands created to receive the signal, process the signal and perform a certain action; and automation is exercised in the coding of the sequence of commands in the specific programming language of the microcontroller. Although this activity does not include sensors, it is possible to exercise the skills mentioned and the knowledge acquired is fundamental for the conduct of the following activities, bearing in mind that the students had no previous knowledge about electronics.

Activity 4: The objective of this activity was to understand the functioning of sensors for considering thinking about smart objects. Thus, the circuit presented in the Figure 1 was assembled by the students. Despite initial friction among students from the larger groups, the activity was quite exciting as they were able to assemble the circuit, program the sensor and see the data being collected in real time. Through the knowledge about the functioning of the sensor and its prototyping, development of the algorithm for data collection and visualization and automation were exercised incrementally the skills of decomposition, pattern recognition, analysis, abstraction algorithms and automation as the previous activity

Activity 5: This activity involved presenting IoT in practice using clouds was successful, despite the difficulties in programming the circuit. All the groups were able to finalize the proposals within the established time frame, being observed the engagement of the students by observing in practice what was studied in theory. Through the knowledge of cloud data storage and retrieval, together with sensor operation, its prototyping, development of the algorithm for cloud collection and storage and visualization and automation were exercised incrementally the skills of decomposition, pattern recognition, analysis, abstraction algorithms and automation as in the previous activity.

Activity 6: Groups of students worked on their projects in the school, without any formal scheduled meeting. They developed the prototypes, which had electronic components such as sensors that were not addressed in the workshop, as well as some prototypes were composed of 2 or more sensors. Through prototyping, development of the algorithm for data collection and visualization and its automation were exercised, in an incremental way, the skills of decomposition, pattern recognition, analysis, abstraction algorithms and automation. They also worked on Cooperation and collaboration skills were developed.

Activity 7: In this activity, 5 out of 8 projects were presented. Three projects were not finished because they spent too much time in initial discussions to generate consensus. Each presented project exposed the problems to be solved; the social improvements for the city; IoT technologies as drivers of development; ethical issues; integrity; privacy; protection of data collected through sensors; and technical concepts on the operation of sensors and microcontrollers in the electronic circuit.

In the first activity (Activity 1), the students presented the idea of a solution for SHC through IoT. In Activities 2 to 5, theoretical and practical concepts were presented, so that they could instantiate the idea. They presented in Activity 7 ideas with feasibility of instantiating: walking stick for the visually impaired in order to assist in locomotion and mapping the limitations of urban infrastructure for accessibility; network of gas sensors in order to monitor the air contamination of the main avenue city; smart garbage dump, capable of detecting the level of garbage, and the authority responsible for cleaning and the population would have access to this information in real time; analysis of the water quality of the city's lake, space frequented by the population for physical exercise and walking; monitoring of the city's garbage dump, in order to know if it can cause any damage to the environment and/or people's health; community garden automation and automation of an aviary, in order to optimize people's time and resources. We could observe that the students' ideas have a relevant social impact.

In our proposal, PC skills were exercised in each activity, as previously described. We understand that investigating whether it is possible to evolve CT skills in a constructive and continuous way is a research space that demands long term case studies and requires a participatory research in partnership with students and teachers. However, we can qualitatively evaluate the development of PC skills through the prototypes developed and presented during the realization of the cycle of activities

In addition to the skills already mentioned, others have been developed such as: (i) collaboration: as the students worked in groups, it was possible to observe the collaboration between them, from the discussion phase, conception, execution and presentation of the project; (ii) conflict resolution: when conflicts arose between group members, some students sought to resolve the conflict by talking with all members; and (iii) creativity: all the projects were conceived and developed by the students themselves using the most different types of complementary materials, to solve their social reality problems.

At the end of the activities, we applied a second questionnaire, with the objective of collecting information on students' perception of participation in the activities. O The questionnaire was applied after the presentation of the final projects, the last activity of the workshop. Out of the 40 students who participated in workshop 34 answered this questionnaire. The other 6 students didn't want to fill it. Of the 34 students responding, 28 were very pleased to participate in the activities; 5 were satisfied; and 1 was dissatisfied, thus showing the workshop's adequacy to the students' expectations.

Regarding students' perception of the amount of content worked in the workshop activities, 23 students responded that the content was adequate, 5 students reported that fewer subjects should be addressed, 4 students reported that there was discussion of many subjects per activity, which made learning difficult, and only 2 students thought it would be interesting to address more subjects. Thus, we concluded that 9 students had difficulty in assimilating all the contents in the workload offered. This difficulty came from the lack of previous knowledge about the topics worked in the workshop. Taking into account the lack of previous knowledge of students, one of the possible solutions to the problem would be to increase the workload. In this way, students could assimilate the contents in an appropriate and/or satisfactory way. Another point analyzed was the organization between theory and practice. For 21 of the 34 students, there was an alignment between theory and practice within the workshop workload, however 11 students responded that much time was allocated to the theoretical part and would like more time in the practical part for handling the Internet of Things materials.

We noticed that the first contact of the students with IoT objects (sensors and actuators) was permeated by doubts and fears of component burning, shocks or errors when connecting the sensor in the circuit. Despite the excitement of working on something different from the school content, it took students a considerable time to put together a simple circuit. However, many students didn't want to go to the break because of the curiosity to manipulate and research how IoT objects work in the electronic circuit. Another point to highlight was the programming of IoT objects. Several students showed difficulties with the syntax of the source code, which resembles the C programming language, causing many doubts and, consequently, an excessive workload consumption in the coding writing. Therefore, we think it is important to use a visual programming language at this stage, so that the student can develop the automation ability in a more efficient way.

Regarding the most difficult contents, the students reported that they had difficulties with the theoretical content, mainly the content related to public data. We understand that this difficulty is related to the lack of previous knowledge and the low workload for the subject, which needs to be inserted with more time so that there is better assimilation by the students.

Another reported difficulty was the handling of IoT technologies, mainly in relation to basic electronics and electronic circuit operation, as they were also new concepts. Add to this the fear of breaking and burning the micro-controllers, sensors and electronic components. The students also reported the difficulty in programming, especially the respondents of the Agricultural course, who had their first contact with programming and algorithmic logic in this course.

When asked if the workshop awakened interest in studying more about IoT technologies, out of 34 students, 22 besides understanding the concepts of IoT, understood it with potential to improve people's quality of life, and that the search for more knowledge about IoT will awaken more opportunities for the development of solutions for SHC. Regarding the interest in public data, 15 out of 34 students responded that the course did not arouse their interest in public data, a fact that may be related to the depth in which the topic was addressed.

To understand the students' feelings about participating in the workshop, we suggested that the students make a report back. For most it was a successful experience with the opportunity to learn new and useful content. Other students reported that they would like the workshop to have more time for practice with the IoT objects. Even when asked if they would recommend the workshop to other students, they answered yes, because it is interesting and useful content, and that through the workshop more people can have ideas for solutions to the most diverse problems of the city.

VI. Conclusions

We propose in this work a pedagogical practice for teaching TC through the use of IoT technologies, considering SHC, open data and data privacy concepts. Our proposal emerged as an interesting activities to students to present these concepts, as well as considered our literature review for understanding the use of IoT to teach CT. In our proposal, the 20-hour workload proved efficient to some extent. Due to the nature of the learning teaching process, some students have had more difficulties in certain subjects, and others more easily. Add to this the fact that most students do not have the minimum prior knowledge of the contents worked on the proposal, which impacted on the individual time needed for learning each student.

We understand that the content of public data can be deeply worked. Consequently, this requires an increase in the workload. In addition, we need a greater workload for handling and programming the sensors, micro-controller boards like Arduino and ESP32 and electronic circuit assembly. Some students also reported difficulties related to the syntax of the Arduino IDE programming language. So, the maintenance or increase of the workload of the proposal should take into account the previous knowledge of the target audience about the topics addressed in the educational practice proposal. Nevertheless, the experience was considered successful in its planning and application, with positive evaluation of the participating students. We understand that the experience can be replicated to different domains and contexts, and presents itself as an innovative way of presenting the area of Computing to students in High School, awakening criticism on the subject, developing PC skills and soft skills, as well as presenting the area as a profession.

It is important to note that understanding how IoT object data are collected, transmitted, stored, visualized and, above all, how to manipulate this data in digital format to then generate information and, consequently, knowledge, is an essential skill for the 21st Century. In this sense, we observe that IoT can be an important tool in the teaching of Computing in primary and secondary Education, because learning can be more significant, since the student can use concepts of computing to solve real problems of their daily lives. On the other hand, in future work, the pedagogical practice proposed in this paper should consider how to assess the achieved level of PC skills by the students.

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