Didactic prototype for the implementation of the STEAM methodology in university electronics courses using the Arduino platform with a constructivist approach to learning

Prototipo didáctico para la implementación de la metodología STEAM en cursos de electrónica universitaria usando la plataforma Arduino con un enfoque constructivista del aprendizaje

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Abstract

In this paper a didactic prototype for the implementation of the STEAM (Science, Technology, Engineering and Mathematics) methodology based on the scientific method and using the Arduino platform for use in the electronics courses offered by the Physics Department of the Faculty of Sciences of the Universidad Nacional Autónoma de México (UNAM) is proposed. The implementation of the STEAM methodology in the electronics courses was carried out under a constructivist approach to learning through the development of an electrical prototype defined by the students and using Arduino. This proposal aims to implement training processes with technological tools that encourage the development of thinking skills, deductive reasoning, logic, inquiry, design, and optimization among students through observation, induction and questions, hypotheses, analysis, and experimentation using the Arduino platform. Arduino is a technological development tool that allows solving problems in different contexts and situations in a simple and affordable manner.

STEAM, TIC, Arduino

Resumen

En este trabajo se propone un prototipo didáctico para la implementación de la metodología STEAM (Ciencia, Tecnología, Ingeniería y Matemáticas) basado en el método científico y utilizando la plataforma Arduino para su uso en los cursos de electrónica que ofrece el programa del departamento de Física de la Facultad de Ciencias de la Universidad Nacional Autónoma de México (UNAM). La implementación de la metodología STEAM en los cursos de electrónica se realizó bajo un enfoque constructivista del aprendizaje a través del desarrollo de un prototipo eléctrico definido por los estudiantes y usando Arduino. Esta propuesta tiene como objetivo implementar procesos formativos con herramientas tecnológicas que incentiven el desarrollo de habilidades de pensamiento, razonamiento deductivo, lógico, de indagación, de diseño, y de optimización entre los estudiantes a través de la observación, inducción y preguntas, hipótesis, análisis y experimentación usando la plataforma Arduino. Arduino es una herramienta de desarrollo tecnológico que permite dar solución a problemas en diferentes contextos y situaciones de una forma sencilla y a un costo asequible.

STEAM, TIC, Arduino

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Introduction

The social, political, economic and health events that the whole world has undergone in recent decades have transformed the dynamics and rules of the game in different sectors such as production, commerce, finance and education. This transformation has made information and communication technologies (ICTs) indispensable tools for the development of these sectors.

In the education sector, ICTs have provided invaluable support in the development and delivery of lectures at all levels of education virtually, remotely and in real time through videoconferencing, as was experienced during the last global pandemic caused by the SARS-COV-2 virus (UNESCO, 2020). Some of these ICTs are video calling platforms such as Zoom (Zoom Video Communications, 2022), Google Meet (Google LLC, 2022), Microsoft Teams (Microsoft Corporation, 2022), Skype (Microsoft Corporation, 2022), among others, and remote laboratories. The latter are tools that help to perform experiments, and to operate equipment or measurement instruments remotely and in real time to a degree similar to physical interaction. Such laboratories are used in the teaching of engineering courses and in research (Cooper, M., 2005; Cooper, M., Donnelly A., & Ferreira J. M., 2002; Division of Electrical Engineering, 2015; Espinosa-Espinosa, M. I., 2022).

During the pandemic caused by COVID-19, education ministries around the world opted for the use of ICT to resume and maintain teaching at all levels. However, this temporary solution revealed that the current education model lacks digital education strategies that take full advantage of the full potential of ICTs. On the one hand, unequal access to the internet results in an unequal distribution of resources and strategies, affecting the most vulnerable sectors. On the other hand, the lack of human capital trained in the use of ICTs among both teachers and students complicated the development of online teaching (UNESCO, 2021).

Based on the above, ICT is no longer an option; it is a compulsory subject that must be mastered by teachers, students and the general population to cope with the demands of today's world. This means that new educational trends and strategies must be oriented to include methodologies in the teaching and use of ICT at all levels of education in order to give added value to conventional courses.

In university education, the trend is for students to acquire knowledge through their own experiences in problem solving, making them an active part of the teaching process and not just listeners. However, we must not lose sight of the fact that one of the objectives of university education is to train human capital with the necessary competences for their insertion in the national and international labour market. This is of vital importance in today's globalised economies that are driven by technological innovation. One strategy to improve higher education outcomes and relevance for the labour market in Mexico is to use the STEAM (Science, Technology, Engineering and Mathematics) methodology that addresses Science, Technology, Engineering and Mathematics in an interdisciplinary, transdisciplinary and integrated way with an experiential approach and application of knowledge for problem solving, while preserving the richness and uniqueness of each speciality. In addition, this methodology would help to train human capital in the use of ICTs (vision, knowledge and skills). in the use of ICT (STEM vision for Mexico, 2019).

The use of STEAM methodology in education generates deductive, logical, enquiry, design and optimisation reasoning in students to solve problems in different contexts and situations (Glancy, A. & Moore, T., 2013). Similarly, robotics is an area of technology that helps to develop students' emotional intelligence and to teach natural sciences in basic courses (Alcocer Menéndez, C. C., 2022; Arévalo Castilla, J. D., 2022).

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The whole world is on the verge of the fourth industrial revolution. This envisages a technological transformation that will modify the way in which humanity lives, works and relates to its environment. The depth and breadth of these changes foretell a transformation of the current social, political and economic structure. The fourth revolution could generate greater social and economic inequality due to its disruptive potential in labour markets. That is, the automation of industry will replace human labour with technology throughout the economic system and will generate a net increase in secure and well-paid jobs for skilled people. However, this process will accentuate the gap between returns to capital and returns to labour.

The future is uncertain, but history suggests that talent and well-trained human capital will be a more critical factor in production processes than economic capital. This will generate a highly segregated labour market in "low-skill-low-wage" versus "high-skill-high-wage" segments (Pérez, M. J., 2016; Schwab, K., 2020).

Today, there is clear evidence that the technologies underpinning the Fourth Industrial Revolution are having a major impact on industry. The innovation and productivity of the Mexican economy will depend on human capital with the skills and knowledge necessary to face increasingly demanding markets with more information and greater technological complexity. For this reason, it is necessary that Mexican students have STEAM training from an early age and throughout their academic life to develop skills and tools that allow them to face new challenges (Jiménez Martínez, K. A. et al., 2019; López Simó, V., Couso Lagarón, D., & Simarro Rodríguez, C., 2020; STEAM Model, 2021; United Nations Educational, Scientific and Cultural Organization, 2019; Santa Maria Santamaría, K. G., 2022; Villarreal Contreras, R., Salas Álvarez, D., & Alemán, A., 2022).

To achieve the objective of equipping Mexican students with competences related to the new challenges, it is necessary to establish pedagogical strategies that promote active, self-regulated, goal-directed, collaborative learning and favour the social processes of knowledge and the construction of meaning (Villavicencio, C., 2017).

The implementation of STEAM methodology in teaching looks promising. The STEAM PA proposes the 5E model as a mechanism for the implementation of STEAM methodology in education. 5E is an effective tool that gives pedagogical certainty to STEAM practices by making them compatible with pedagogical theory validated by educational research (Bastida Izaguirre, D., 2019).

Despite all the benefits of a STEAM methodology for university chairs in Mexico, there are aspects of infrastructure that limit the implementation of this type of methodology. In order to develop a strategy of this type in higher education, properly conditioned enclosures, specialised measuring equipment or instruments, electronic and electromagnetic simulation software licenses, 3D printers, among others, are needed, which represents a substantial economic investment that many Mexican universities cannot afford. In addition, highly trained personnel are needed in each of the disciplines covered by the STEAM methodology: Science, Technology, Engineering and Mathematics.

One option for implementing the STEAM strategy at the university level in Mexico at low cost, without the need for specialised infrastructure or highly trained human capital and with outstanding results is the use of the Arduino platform. This platform has several characteristics that converge with the STEAM methodology. That is, it makes use of the four areas covered by this methodology at different levels through a hardware/software development environment that is easy to access and understand.

It is also an open-source platform that has generated a synergy of added value between specialists, professionals, students and amateurs from different disciplines that converge in the use and contribution of new tools that have enriched the platform. This has allowed the development of a large amount of literature that helps in the process of assisted or self-taught learning.

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One of the greatest qualities of this platform is a user-friendly development environment that allows students interested in developing technological applications, without the need for a vast knowledge of electronics and computer programming. This awakens a fervent interest in students to learn and develop projects as they overcome the difficulties they face (De Melo, *et al*., 2014; Huang, B., 2015; Titon, W., & García Ramírez, A. 2018; Wood, B. & Ganago, A., 2018). These features allow the Arduino application environment to range from entertainment and leisure projects to space research (Galadima, A. A., 2014; Munera, J. M., *et al*., 2020).

Every embedded system has its own limitations, and Arduino is no exception. But these limitations can be overcome with the experience of the developer, or with the help of a teacher or the community in the areas of electronics, microcontrollers and computer programming to adjust the development board to the prevailing needs.

This document presents a didactic prototype to implement the STEAM methodology based on the scientific method and using the Arduino platform in the electronics courses of the physics department of the Faculty of Sciences of the National Autonomous University of Mexico. This proposal is developed from the need to implement training processes with technological tools that encourage the development of thinking skills among students through observation, induction and questions, hypotheses, analysis and experimentation (scientific method) using the Arduino platform.

The strategy used for the implementation of the STEAM methodology takes a constructivist approach to learning. With this approach students play a leading role in their own learning process through decision-making and direct management in the solution of a problem or development of a project. The logbook technique was also used to keep a record of the development process of a proposed solution to an identified problem or a developed prototype.

To achieve the objectives of this proposal, the students attending the courses form working teams. Each team is formed by three students, and in turn, each team proposes the development of an electrical or electronic prototype that studies a physical phenomenon or helps to solve a problem in their environment using the Arduino platform (García, N. Y. G., & Navarro, K. E. O. 2.4).

This document is made up of four sections; the first one is called Methodology, where the points that are part of the proposed strategy for the implementation of the STEAM method in university electronics courses are described. The second section is called the Arduino platform. In this section the most important features of this platform that help the implementation of the STEAM methodology in the courses are presented. The third section is called results. This section presents the results of a diagnostic study carried out on students who took the electronics course. The objective of this test is to know the level of knowledge that students have at the beginning of the course in the areas of electronics and computer programming. Similarly, evidence is presented of the projects carried out by the students during the electronics courses, where the didactic prototype proposed for the implementation of the STEAM methodology was applied. Finally, the fourth section presents the conclusions of the work.

Methodology

The methodology used for the STEAM implementation using the Arduino platform in the electronics courses through the development of a technical project is based on eight parts:

1. Lectures on electronics/computer programming topics and feedback from the teacher on the project to be developed.

2. Observation and identification of a problem to be solved by the students.

3. Research, and acquisition of information and knowledge about the problem to be solved.

4. Generation of guiding questions to help develop a proposed solution.

5. Proposal of a solution to an identified problem using the Arduino platform.

6. Development of the proposal using the Arduino platform.

7. Analysis of results.

8. Monthly presentations of the progress of the proposed project by the students.

Figure 1 shows the block diagram of the proposed methodology. The blocks represent the components and functions of the didactic prototype proposed for the implementation of the STEAM methodology in university electronics courses. This prototype is oriented to the development of thinking skills, collaborative (team) work and problem solving using the Arduino platform.

1. The first block is defined by the courses focused on providing students with the theoretical, practical and simulation tools needed to get involved in the world of electronics. To achieve this objective, the lectures are divided into three parts; the first corresponds to theoretical classes where basic concepts definitions are covered, teaching the theory of electrical circuits, operation of active electrical components such as the diode, the transistor, the operational amplifier, among others. These courses also cover electronic analysis and design. This is done with the support of ICT such as the use of simulators and applications that facilitate the understanding of a concept or the behaviour of an electrical device.

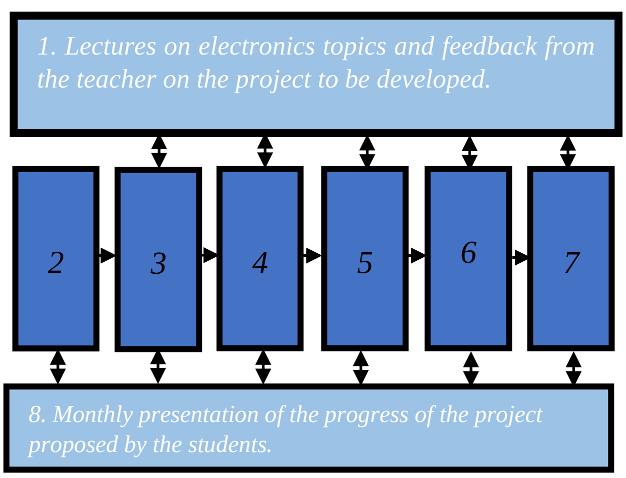


Figure 1 Block diagram of the proposed didactic prototype for the implementation of the STEAM methodology using Arduino in electronics courses at university level

The second part focuses on the teaching and use of semi-professional and professional simulation software such as Proteus (Proteus Design Suite Software, 2022), LTspice (Analog Devices, 2022), TinkerCAD (Autodesk, Inc, 2022), among others, which allow the student to check the operation of the electrical circuits analysed in the theoretical classes virtually.

The third part corresponds to the practical section, where the student in a real environment (laboratory) builds the electrical circuits analysed and characterises them electrically using basic measuring instruments such as ammeters, voltmeters, ohmmeters and oscilloscopes. The student then compares the theoretical, simulated and practical results. These lectures are taught during a whole educational semester.

In addition, the lectures are adapted throughout the semester to provide students with the necessary tools to develop their projects. For example, some classes are used to cover computer programming using the Arduino IDE (Integrated Development Environment). With these classes, students should be able to develop their scripts according to the needs of their projects, and make use of the mathematical processes acquired throughout the physics degree to help solve the problem posed.

In addition, the teacher provides feedback and guidance on the projects selected by the work teams throughout the educational semester.

2. The second block is observation and identification of a problem to be solved. Here, we work on the collaborative part of observation and approach through the generation of work teams, formed by three students each. Each team must identify a problem to be solved or a physical phenomenon to be studied. The identification of the problem or phenomenon to be studied must be the result of a process of observation and analysis of the environment that each work team carries out.

Once the problem to be solved or phenomenon to be studied has been detected, the team makes a short presentation of the topic to be developed, where the name, objectives and scope of the project are proposed. This block has a period of two or three weeks during the educational semester.

3. Block three corresponds to the research and acquisition of information on the identified problem or physical phenomenon to be studied. Here the teams review, research and acquire information about the problem to be solved. As well as existing solutions in the published literature. In other words, they develop the state of the art of the subject to be dealt with. This block is developed from the selection of the project to its final presentation.

4. With the information acquired in block three, the teams formulate a series of guiding questions that can be descriptive, comparative, defining, evaluative/normative, etc., that help to solve the problem identified. In this way, block four is covered in a period of two weeks.

5. Block five is the development of a proposed solution using the Arduino platform. With the help of the information acquired in blocks one, three and four, the students have the elements to propose a technical proposal using the Arduino platform that can solve the identified problem. Here a technical analysis of the needs of the proposal is made and the appropriate elements of the Arduino platform are chosen to cover these needs. In this block, the working teams make their second progress presentation, where they present the problem to be solved, the technical tools to be used and the possible solutions they will have. All of this is achieved on the basis of the work carried out in the previous blocks. In this second presentation, the teacher gives feedback on the proposals presented by the teams in order to guide, delimit and enrich the scope of the project. The rest of the working teams can also contribute to this feedback.

6. In block six the proposal is developed using the Arduino platform. In this part, the students, with the information acquired to solve the identified problem, focus on developing two aspects that help to solve the problem, one is at the software level and the other is at the hardware level.

At the software level, the students develop the script or computer scripts necessary to execute a series of tasks focused on operating the Arduino hardware that forms part of their proposals. For the development of the scripts, structured or object-oriented programming can be used according to the needs of the project.

On the hardware side, students focus on making the electrical connections, signal conditioning and power levels needed for the application.

Once the prototype is completed, it is subjected to electrical and electromagnetic characterisation. In the electrical characterisation, the voltage, current and power levels that the prototype requires for its operation are measured. Subsequently, a comparison is made between the estimated and measured theoretical values to verify that the prototype is within the parameters set out in the project.

In the electromagnetic characterisation, the prototypes are subjected to radiated and conducted emission tests to determine the degree of electromagnetic disturbances that can be generated during normal operation. These tests are performed in the semi-anechoic chamber located in the science faculty of the National Autonomous University of Mexico (UNAM), campus Ciudad Universitaria. This test is not mandatory in the proposed didactic prototype, because few universities can have this kind of infrastructure. However, since the Faculty has this infrastructure, it was decided to use it to enrich the prototype and to induce students in an area of high added value in electronic design, which is electromagnetic compatibility (EMC). This block is developed from the second month of the academic semester until days before the presentation of the project. Figure 2 shows a photograph of the semi-anechoic chamber used.

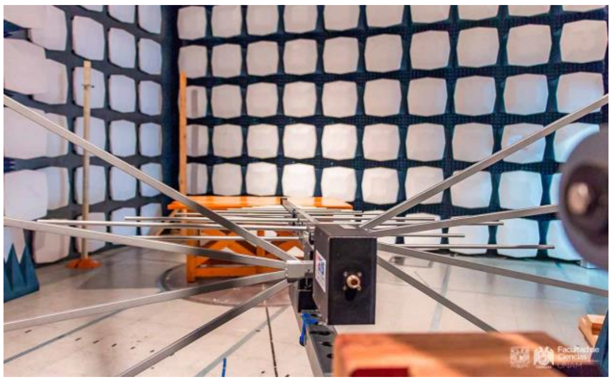


Figure 2 Semi-anechoic chamber of the Faculty of Sciences, UNAM (Faculty of Sciences, 2022)

7. Block seven corresponds to the analysis of results. Here, students subject their prototypes to field tests to determine their performance. Depending on the prototype and its objectives, the field tests provide a set of data that can be analysed statistically, or simply determine the performance of a defined task.

8. The eighth block, known as the presentation of the topic to be developed by the work teams (students), is made up of five presentations made by the teams over the course of a semester, one per month. The aim of these presentations is, on the one hand, to show the progress made by the students in the development of the prototype, and on the other hand, to talk about the problems encountered during the development of the prototype and their possible solutions. Similarly, these presentations are used for feedback and guidance from the teacher and possible contributions from the rest of the students on the project presented. In the last presentation, the work teams show the finished project and describe how it works, as well as all the problems encountered and their solutions during the development of the prototype.

Arduino Platform

Arduino is an Open Source project consisting of a free hardware platform and an IDE to develop scripts or computational routines that perform specific tasks. This project allows the development of digital and interactive devices that can detect and control real-world objects in a simple and inexpensive way.

The Arduino platform has several interesting features like all Arduino products. They are distributed as free hardware and software, under the GNU General Public License (GPL) and GNU Lesser General Public License (LGPL) that allow the manufacture of the Arduino boards and the distribution of the software by anyone interested in doing so.

The Arduino software consists of two elements, the first is a computational development environment (IDE), which is based on the processing environment and the structure of the Wiring programming language. The second is a bootloader that runs automatically inside the board's microcontroller as soon as the board is powered up (Arduino.cc, 2022).

In addition, the platform has an extensive range of development boards with different technical capabilities, and a wide range of external modules or Shields, such as actuators and sensors for specific uses that require basic configuration processes to operate. In addition, the cost of the development boards and their add-ons are affordable. Arduino boards are commercially available as development kits and assembled boards using the do it Yourself approach. The boards use various microcontrollers and microprocessors (8-bit AVR, Cortex M3, 32-bit ARM, etc.) from the company ATMEL AVR in a "minimal system" configuration (Microchip Technology Inc., 2022).

ARM and AVR architectures are not the same, so their instruction sets for assembly-level programming are not the same either. This leads to incompatibility in some software libraries developed for a specific architecture. However, all models of Arduino boards can be programmed and compiled in the same IDE without any change. This is because the IDE compiles the original code to the selected board version. All Arduino boards are programmed through a computer using the serial/USB (Universal Serial Bus) communication protocol. These features avoid the use of external microcontroller programmers that would make the Arduino platform more expensive.

Expansion boards (shields) can be easily connected to an Arduino development board through their input and output ports (Shields-Arduino Official Store, 2022). Shields complement and extend the functionality of the board used. They allow the connection of sensors for the measurement of physical variables and external communication modules that use the frequency hopping spread spectrum technique, Bluetooth, (Bluetooth Special Interest Group, 2022) and digital modulation, Wireless Fidelity, WIFI, (WIFI Alliance, 2022). As well as communication modules equipped with mobile and satellite communication technology such as Global System for Mobile Communications, GSM, (GSM Association, 2022), and Global Positioning System, GPS, (GPS.Gov., 2021), respectively.

WIFI technology provides access to the internet network, which enables Internet of Things applications. This makes it possible to operate the application remotely and store data in the so-called cloud. With GPS and GSM technologies, Arduino boards can be connected to a satellite network to obtain the geographical position of a person, animal or thing of interest and to the mobile phone network to make/receive a call, send/receive a short SMS message and make use of applications such as Google Maps (Google, LLC, 2022), respectively. This allows a student to acquire knowledge of today's most commonly used communication systems and processes without the need to purchase expensive, professional equipment. Figure 3 shows the Arduino board with its multiple Shields that allow the development of a wide variety of applications focused on different disciplines.

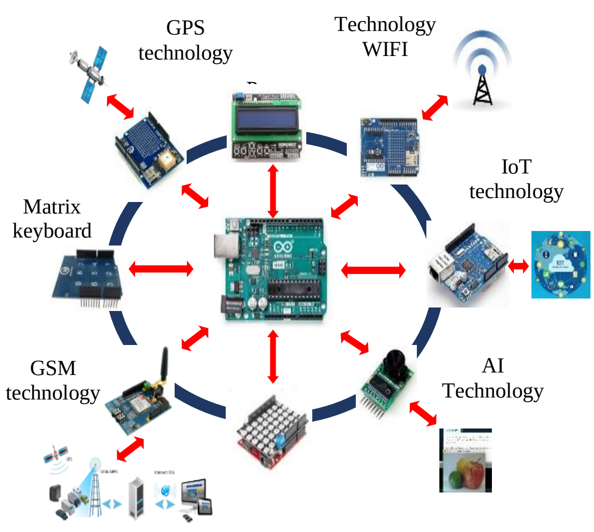
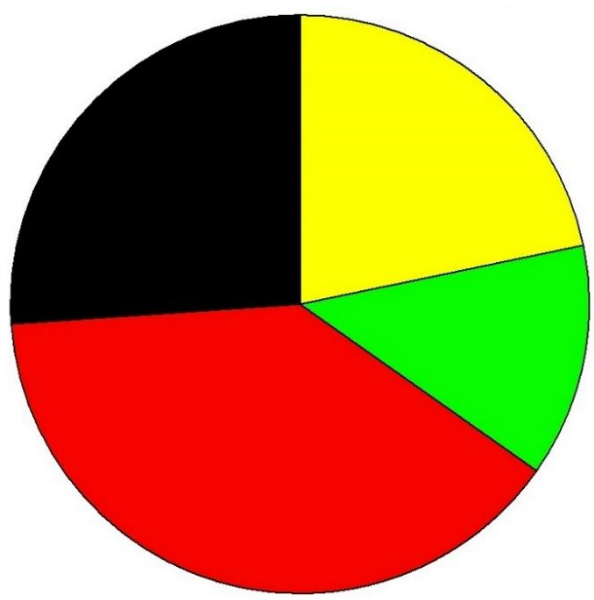


Figure 3 Arduino and its Shields

Results

The prior knowledge of the students who took the electronics courses in the areas of programming on the Arduino platform and electronics was determined with a diagnostic test of 46 students. From where the following results were obtained; 26.08% of the students only had prior knowledge in electronics, 39.13% had prior knowledge in computer programming with the Arduino IDE, 13.04% had knowledge in both areas and 21.73% had no prior knowledge in either speciality. The results are presented in graphic 1.

Despite the fact that only 13.04% of the students surveyed had knowledge in both specialities, with the implementation of the proposed didactic prototype it was possible that at the end of the courses 100% of the students acquired the necessary skills in both areas, developing critical thinking and experimentation.



- 26.08% Knowledge of electronics.
- 39.13% Knowledge of programming (Arduino IDE).
- 13.04% Knowledge in electronics and programming.
- 21.73% No knowledge of electronics and programming.

Graphic 1 Percentage of students with previous skills in electronics and programming (IDE-Arduino) at the beginning of the electronics course

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With the skills acquired during the educational semester, the students adequately developed the proposed projects. These are within a wide range of applications and problems to be solved such as a geolocation system for vulnerable people using commercial modules that have GSM communication technology, and GPS. These modules are connected to an Arduino Uno board where the script that controls the operation of the system is stored. The material used is a breadboard, Arduino Uno and the A9G module. Figure 4 shows the prototype of the geolocator.

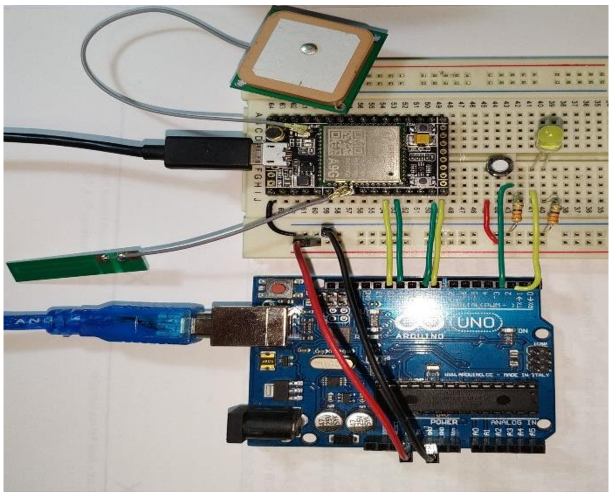

Figure 4 Geolocation system

The project called vital signs station aims to measure the temperature, blood oxygenation and heart rate of a patient. It also makes use of the Internet of Things technology to send the collection of acquired data to the cloud. This project uses an ultraviolet (UV) lamp for self-sterilisation of the device's contact points with patients. The project used a liquid crystal display (LCD), 1602A, ESP8266 NodeMCU board, Max30102, MLX906614 modules, a breadboard and a 5V battery bank. A photograph of the system is shown in figure 5. Figure 6 shows a picture of the project called mini-station for monitoring environmental conditions. The aim of this project is to measure the concentration of carbon dioxide (CO2) on university campuses in order to prevent possible infection by the SARS-COV-2 virus. In addition, it has the ability to measure temperature and humidity of the campus. The acquired CO2, temperature and humidity data are transmitted via Bluetooth to a smartphone for remote monitoring of the site. This project used the Arduino UNO board, the DHT11 sensor, the MQ135 air quality sensor, the bluetooth module model HC-05, and three LEDs as signalling devices.

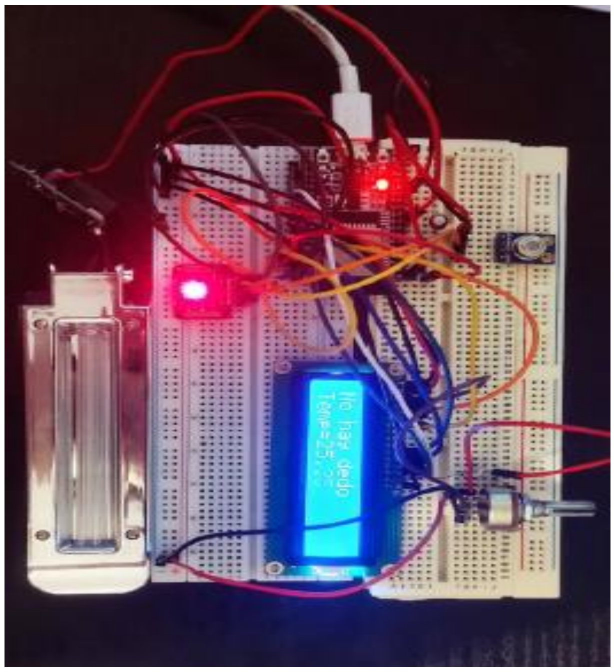

Figure 5 Vital signs station system

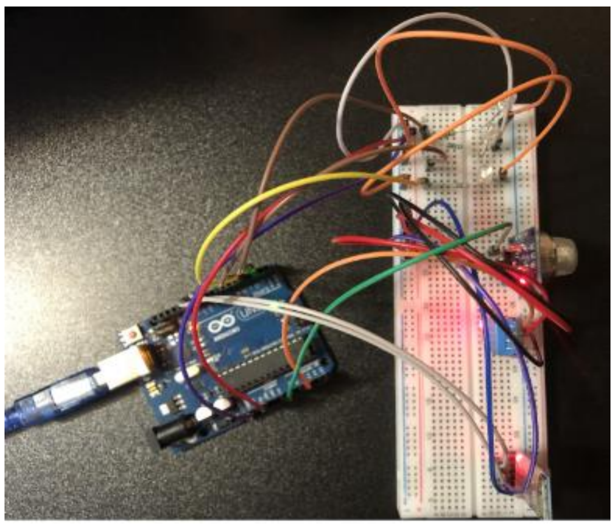

Figure 6 Mini-station for monitoring environmental conditions

Figure 7 shows the images of the automatic home composter project whose objective is to measure the thermodynamic variables involved in the composting process such as temperature and humidity. In addition, it is responsible for the control and operation of the compost aeration process using a 0.5 horsepower (hp) AC motor. The motor is recycled, as it was removed from a disused washing machine. The motor operation process is controlled by the Arduino UNO board and a solid state relay. The project used two cylindrical plastic containers with a volume of 19L each, an AC electric motor, an Arduino UNO board, a wooden structure, a FOTEK SSR-10 DA solid state relay, the DTH11 sensor, three LEDs, and a micro push button.

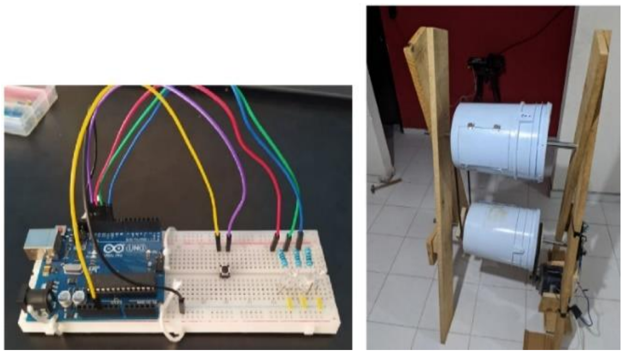

Figure 7 Automatic home composter

Figure 8 corresponds to the photograph of the Arduino heart rate monitor project. The project measures a person's heart rate using an ARD-366 reflective type sensor, an Arduino Uno board and a liquid crystal display (LCD). The readings acquired by the system are displayed on the LCD screen (16x2).

Other projects were blind spot removal in automobiles using ultrasonic sensors and the Arduino board, encryption machine based on the enigma machine using the Arduino board, among others.

As can be seen, all the projects are made up of two elements; software and hardware. In each of these elements, tools from the areas of science, technology, engineering and mathematics (STEAM) were used to a greater or lesser extent to achieve the proposed objective. The average cost per project is $1500.00 Mexican pesos. This is an affordable cost for a team of three students.

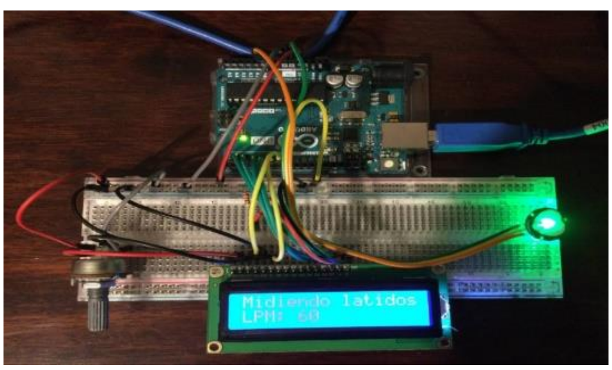

Figure 8 Heart rate meter with Arduino

Conclusions

The strategy used for teaching STEAM methodology with a constructivist approach to learning, allowed students to play a leading role in their own training process through decision-making and direct management of project development.

This training process was accompanied by theoretical-practical lectures and specific advice from the teacher. In this way, the proposed strategy was enriched, allowing the students to develop analytical and experimental skills for the solution of a given problem.

The implementation of the STEAM methodology with the help of the Arduino platform in the electronics course was developed from the need to implement training processes with technological tools that encourage the development of thinking skills among students through analysis and experimentation.

With the Arduino platform, the proposed objectives are achieved at an affordable cost. In addition, this platform allows different areas of application to be explored, from the measurement of a physical variable such as temperature, humidity, etc., to the world of communications and the internet of things. This allows students to develop a project in its entirety from the problem statement to the remote operation of the prototype and data visualisation through different applications of the Internet of Things.

This didactic prototype proposed for the implementation of the STEAM methodology using Arduino must continue to mature in order to fine-tune its development so that students acquire the proposed skills in a more efficient way. A quantitative study of the acquisition of STEAM tools by the students also needs to be carried out and based on this a search for didactic techniques to improve the proposed didactic prototype needs to be carried out.

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