DelphiCare 6.0
A Project-Based Learning Approach

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***Abstract*- Sometimes, it is interesting to approach an academic laboratory class from a different perspective. This paper takes on the experience of a group of mechatronic engineering students taking an academic course on laboratory of integral electronics. The students were asked to design a system capable of measuring three vital signs of a patient. To achieve this, they use the knowledge acquired in their career up to that moment to manage other knowledge that was required. In order to carry out the project, a project-based learning methodology was followed. This experience allowed the students involved to solve a real problem with a product that responded to the specifications of cost, portability and information available from a mobile device, as well as meeting the requirements to revalidate their laboratory subject matter.**

Keywords - project-based learning; vital signs; sensors; mobile applications.

I. INTRODUCTION

The realization of projects that introduce students to the solution of real-life problems that are related to a particular subject constitutes a commonly employed method within engineering. Often referred to as the Project Based Learning (PBL) technique, it was defined as a formal method by the end of the XIX century by William Heard Kilpatrick [1]. It was renewed during the decade from 1960s as it became popular again, and continued to be used up to current days. In [2], PBL is defined as a methodology that enables students to obtain the required knowledge and key skills from the XXI century, through the development of projects that address and solve real life problematics. Some of the core features are:

1) The students are capable of becoming the protagonists of their own learning as they develop their autonomy and responsibility, since they are in charge of planning, organizing the work, and elaborating the product that attempts to overcome the established problematic.

2) The teachers change their main role to a support and guidance role.

3) It enables users to obtain relevant and discipline-related skills, some of which are: teamwork, problem solving, responsibility, spoken and written communication, analysis and synthesis of gathered data, experiment development, socializing with external environments to college, among others [3].

Despite this method being defended by multiple authors, researchers and teachers, it is relevant to take into consideration some unfavorable elements that come with it. For instance we can mention the implementation costs, the location where the project will be developed, the communication towards the final users who will be using the product, and finally, the time accessibility regarding the involved students due to the project being developed in parallel with the rest of the college classes. In order to implement this didactic technique, a ten-step methodology (see Table I), was followed.

TABLE I. STEPS TO CARRY OUT PBL

Step	*Short description*
1	Topic selection and guide question definition. What is known already?
2	Group and role assignment.
3	Defining a real product or final challenge. Setting goals and skills to reach and the criteria to evaluate them.
4	Planification. Establishment of the job's schedule, specifying tasks, who is responsible for those tasks, and deadlines.
5	Investigation. Revision of previous concepts, new required concepts and information research.
6	Analysis and synthesis. To share gathered information, to contribute and debate ideas, to formulate hypotheses, to structure information and to decide among team members the best solution.
7	Product elaboration. To apply the learnt design techniques (use its methodologies).
8	Presentation of the product to team members.
9	Collective answering of the initial question. Following the presentation, students must ruminate in order to collectively answer the starting question.
10	Appraisal and self-appraisal. The teacher must evaluate the work in compliance with a defined rubric and propose a self-appraisal activity to the students.

Under the previously described context, this work has as its purpose to show an experience applying PBL. The work has been performed during the period between August and December 2019 for the laboratory of integral electronics class, in the seventh semester of the mechatronic engineering career, Tec de Monterrey, campus Laguna, Mexico. As the class name implies, the course proposes the realization of 8 to 10 laboratory practices in which the students get to apply the acquired knowledge from two subjects from previous semesters: electronics and applied electronics. The student's work culminates with an integrating project. For a few years, this project has been oriented towards the design and construction of a domotic house, where a series of electronic devices and sensors guarantee three basic elements: comfort, security and the saving of non-renewable resources.

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In this course, we came with the idea of changing the project's subject to a new one: the construction of a device that allows the measurement of three vital signs from a person. The idea had as its background other similar works developed by this paper's author with students from eighth and ninth semester from the mechatronic engineering career. Some questions arose from this idea: Can a mechatronic engineering student from seventh semester accomplish this task? What knowledge the student does not master, but needs to apply on the design, nonetheless? Is one semester enough time for its execution? The idea was proposed at the beginning of the course to a group of 14 students, from which, 5 students felt motivated and committed to its construction. The goals of the work were defined as shown in Table II.

TABLE II. GENERAL AND SPECIFIC GOALS OF THE WORK

Main goal	To apply the PBL approach in order to solve a real-life problem, within a class from seventh semester of mechatronic engineering.
Specific goals	1. To design, mount and test a mechatronic device that allows a real time measurement of temperature, blood's oxygen and an electrocardiographic signal from a patient while it is displayed on a mobile device. 2. To encourage the obtainment of new knowledge not seen in class. 3. To promote teamwork among the students. 4. Spoken and written presentation of a functional designed prototype.

The paper is structured as follows. Section 2 describes the approach taken to address the proposed project. Section 3 covers the results achieved until the writing of this paper, which are not definitive as it is a work-in-progress. Finally, in Section 4, conclusions are discussed.

II. METHODOLOGY

As it can be appreciated, part of the student's group followed the traditional final project while a group of five students chose to participate in this new experience. With the latter ones, a group was formed whose students were exempt from making the regular laboratory practices, so they could dedicate their whole time and attention to the solution of the established challenge. Taking into consideration the methodology to apply PBL, the following stages were presented:

1) Starting question: Is it possible to design a mechatronic device capable of measuring three vital signs from a person, with the device being portable, low cost, and accessible from a mobile device?

2) Selection of a team leader.

3) Design of the rubrics to evaluate the project and the definition of the required skills:

a) Discipline: To design, build, and test prototypes of innovative mechatronic devices.

TABLE III. WORK PHASES

Phase	***Action***
1	Circuit board: oximeter, temperature
	Finish prototype EGC signal
	Pulse in Arduino programming
	Oximeter Thimble
	Attach the components to the thimbles
	Accommodate and couple the circuits and thimbles to the chassis
	Digital filter programming
	Couple positive and negative voltage supply
2	Arduino-App communication
	Android application
	Design and manufacture new Chassis
3	Research for the integration of new sensors
	Start with the prototypes of the new sensors

b) Transversal: Teamwork, knowledge self-management and spoken and written description of the project.

4) Definition of work schedule (Table III).

5) Analysis of the required knowledge:

a) Previous: Signals analysis, electronic components, sensors, design of mechanical parts, and microcontrollers.

b) Self-studied: Development boards, mobile application development, wireless communication, sensing of oxygen presence in blood and the electrocardiographic signal.

6) This point summarizes the stages 6 and 7 of the PBL methodology, applying the general steps of the Ulrich-Eppinger mechatronic product design methodology [4].

7) At the moment of writing of this paper, phases 8, 9 and 10, from the PBL methodology, were in process.

III. PARTIAL RESULTS

To present the results obtained so far, we refer to stages 3 and 5 of the PBL methodology. In stage 3, it was very important to verify the acquisition of the defined disciplinary and transversal competences. Stage 5 allowed to determine what was the new knowledge that students had to manage independently.

The disciplinary competence proposed the construction, assembly and testing of a prototype enabling to measure three vital human signs: temperature, oxygen concentration in blood and an electrocardiographic signal.

The block diagram in Figure 1 presents the process of the prototype.

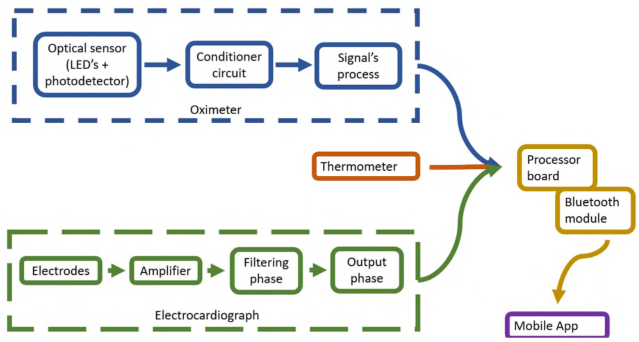

Figure 1 Delphi's block diagram.

Next, a brief explanation is given about the implementation and obtained results, with the help of the block diagram, and gained knowledge.

A. Temperature Measurement

The temperature module of the system consists of the MLX90614 sensor [5], which is an infrared thermometer suitable for measuring temperatures in the necessary range between 20°C and 50 °C, with digital outputs of 17 bits. The sensor provides an output using the I2C protocol for maximum resolution (0.02°C). The sensor has a default range of temperatures between -40 °C and +85 °C. The given temperature value is the average temperature of the object detected by the sensing field from the device. The accuracy of the sensor is of 0.5 °C at room temperature at 25 °C. This sensor is compatible with the analog pins of Arduino.

The temperature data obtained through the device was compared against measurements made with a thermometer, as shown in Table IV. Observe that the collected data in both cases is very similar.

TABLE IV. WORK SCHEDULE

DelphiCare	*Thermometer*
37.48	37.1
37.24	37
36.94	36.8
36.7	36.6
36.52	36.5
36.3	36.2
36.14	36.5

B. Measurement of Oxygen Concentration in Blood

The oxygen sensor was designed from scratch. The SpO2 sensor (oxygen concentration in blood) [6] is based on the principle of pulse oximetry. It generates two beams of light, one of them in the red light spectrum (wavelength: 600nm-750nm) and the other in the infrared spectrum (wavelength: 850nm - 1000nm) and measures the amount of light that is transmitted through the index finger and reaches the photodetector, in this case a photodiode connected to a current/voltage converter made out of operational amplifiers.

The oximeter is composed of three main parts: the optical sensor, the conditioning circuit, and the processing board. Table V shows the readings obtained by the DelphiCare's oxygen sensor, compared against a commercial sensor.

TABLE V. OXYGEN READINGS

Oxygen Saturation (%SpO2)	
DelphiCare	*Commercial Sensor*
98	98
99	98
98	98
98	99
99	99
99	99

C. Electrocardiograph

There is a large number of circuits that measure the electrocardiographic signal. One of the goals of the DelphiCare was to obtain a system that was low cost and had a large portability in comparison with similar systems. Finally, a circuit that obtains a signal from the heart was chosen and built. As it is shown in the block diagram in Figure 1, the signal is obtained through a series of electrodes connected to the chest of the user. After collecting the said signal, it is then subjected to several amplifications and filters, so it becomes easier to be identified and to work with before reaching the analog port of the Arduino board and finally being transferred to the mobile app. The resultant signal is shown in Figure 2.

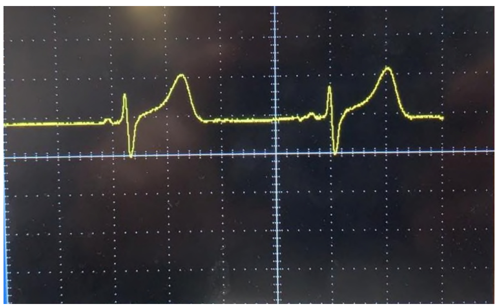

Figure 2. Resultant electrocardiographic signal.

D. Processing Board, BT Module and Mobile Application

The goal of the mobile application is to offer the user an intuitive and reliable way to communicate with the different sensors. The application is planned to perform a synchronization process with a server in order to store the incoming information in a database; the server shall display that data on a Web platform for physicians to analyze. In other words, the objective of the mobile application is to serve as a bridge between the user, the sensor and the server.

The application shows a main menu where the user is prompted to choose a sensor to start a reading (Figure 3).

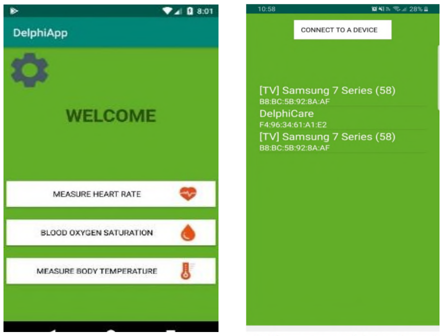

Figure 3. Mobile application menu and discovered bluetooth devices.

Before any reading is performed, the user must connect the mobile device to the DelphiCare device by means of an RFCOMM channel established via bluetooth. The application is capable of starting the connection from within, so the user does not need to minimize the application nor use the phone's built-in configuration app in order to start trading data with the sensor.

The user is able to select a device to establish a connection with, and once done, the buttons to start the measurements with any of the three integrated sensors on the DelphiCare are enabled.

As expected, there are three main use cases: measure heart rate, measure blood oxygen concentration, and measure body temperature. In the first case, the user will be asked to put the electrodes on their chest and press the confirmation button in order to start the reading process. Once the measuring is finished, the user will be shown a graph with the acquired data plotted in order to achieve a proper visualization. In the second and third case, where the user can measure their oxygen saturation and body temperature, the user will be asked to insert their index finger into the corresponding finger grip and wait a couple of seconds before showcasing the results.

Currently, the application is designed to work on Android devices only, as it is still being used as a proof of concept. The Java programming language was selected as the technology for development because it is highly flexible and, contrary to the most recent Android development language released, Kotlin, Java has a huge legacy, and, therefore, the learning curve is very straightforward. Moreover, there is an enormous amount of online resources available for research.

E. New Knowledge Management Required

As expected, this project required to manage the following information:

1) Arduino UNO board. This board was studied and used in order to take advantage of its analog ports, voltage source of 3.3V, the MLX 90614 library (used for infrared thermometers), functions for reading analog inputs, outputting and signal filtering.

2) Oxygen concentration in blood: the use of optoelectronic techniques (visible and infrared light), pulse oximetry, light absorption principle (Beer-Lambert law).

3) Electrocardiographic signal: use of high gain sensors aimed to sense biomedic signals.

4) Wireless communication through a Bluetooth module.

5) Mobile app design using Android Studio and the Java Programming Language.

IV. CONCLUSIONS

In this paper, we reported on the student's progress throughout their experience in designing a system capable of measuring three vital signs of a patient. This project has shown how the students had experimented and accomplished the established goals using the Project Based Learning method. As for the project itself, it is highly interesting to observe how current technology can be integrated into past technology in order to renew it and scale it towards more complex systems. The usage of mobile phones for daily and recurrent services has successfully proven to be easier and cheaper, in this case, there was no difference. This powerful tool will certainly allow for future escalation and spreading of the DelphiCare system.

As noted before, this work was submitted to be considered before completing all the phases from the PBL methodology. However, it is worth mentioning some results and information gained through the process:

1- A prototype from a mechatronic device was implemented, allowing the measurement of three vital signs of a human being, applying the PBL approach. The device is simple, portable and low cost (lower than 3000 MXN pesos).

2- Through the course of the semester, the students showed progress, which was proved by oral and written presentations, partial and final tests, which were received and evaluated with their corresponding rubric form.

3- In order to reach a solution, the students had to apply the gained knowledge.

4- The project covered 80% of the program from the class, from a different didactic approach.

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