Solution for Real Problems through Research by Undergraduate Students

René Joaquín Díaz Martínez
Tecnológico de Monterrey
Torreón, México
email: renejdm@tec.mx

Rafaela Villalpando Hernández
Tecnológico de Monterrey
Torreón, México
email: rafaela.villalpando@tec.mx

Ramiro Saldaña Acosta
Tecnológico de Monterrey
Torreón, México
email: sramiro@tec.mx

Juan Francisco Medina Leal
Tecnológico de Monterrey
Torreón, México
email: A01234038@itesm.mx

Irene Reynoso Anguiano
Tecnológico de Monterrey
Torreón, México
email: A01232645@itesm.mx

Liliana Lizeth Luevano Rosales
Tecnológico de Monterrey
Torreón, México
email: A01231531@itesm.mx

***Abstract*— The present work gathers all the experience and knowledge from a group of students of last semester, taking the course entitled "Project of mechatronic engineering", which focused on actual problems of the local region. This class used an investigation method to approach these problems and teach students about self-learning. The objective of this project was to show students how the theory learned in school can be applied on the field.**

***Keywords*— inquiry-based learning; project; challenge; image processing.**

I. INTRODUCTION

In many situations, undergraduate students struggle to identify the relationship between the knowledge they have acquired throughout the course of their bachelor studies and their future jobs. Some manage to apply their studies through internships in their field, where they develop specific tasks for the companies they work for; others get involved in projects of interest to those entities and develop other abilities through research.

The current tendency to solve these problems is the linkage through university-industry projects that can occur through different pedagogical approaches, for example Research-Based Learning (RBL). This approach consists in applying teaching and learning strategies that aim to connect research with teaching. [1]. Berkeley, Warwick, MIT, Oxford, among others, are prestigious universities that promote this practice.

Pedaste et al. [2] identify and summarize the main characteristics of the RBL and set out the five phases and subphases, which are written in parenthesis, that distinguish it (see Figure 1): orientation, conceptualization (questioning and hypothesis generation), investigation (exploration, experimentation and data interpretation), conclusion, discussion (communication and reflection).

The authors did not find a framework which could gather and elaborate on the five phases and subphases exposed above, which allowed them to define the phases and subphases in what they called the Research Cycle, as shown in Figure 1.

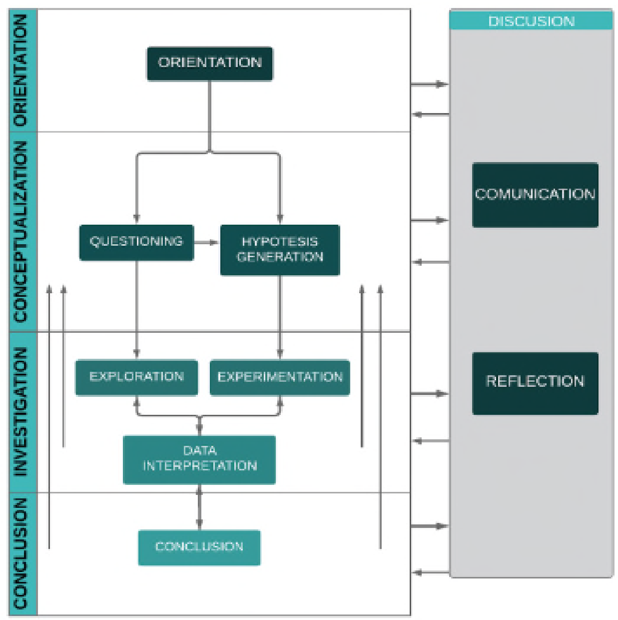

Figure 1. Research Cycle.

It is important to mention three elements of reference [2]:

1) The formulation of the technique is useful as guidance for those who desire to incorporate the pedagogical approach of RBL in their classes.

2) The presence of the discussion phase running parallel to the other phases provides a method in which designing is constantly happening, and it is not necessary to wait until the end to make adjustments because pondering and communication can be done at any moment.

3) Depending on the available information regarding the problem, three approaches can be proposed by students to develop the project: based on data, based on a hypothesis starting from a known theory, and based on questions that allow the formulation of a hypothesis. This last one is considered to come from the second.

Among the advantages that RBL offers, it can be mentioned that it allows better mentoring relationships between the professors and the students than traditional teaching, which results in improved learning and retention in undergraduate students. Also, enrollment in postgraduate education might be increased. In addition, students develop creativity, problem solving and intellectual independence; they also develop an understanding of research methodology. Finally, RBL promotes a culture oriented towards innovation. The other pillar that supports this work is Applied Research (AR). The term "Applied Research" was popularized during the twentieth century to refer to the type of scientific studies aimed at solving problems of daily life and controlling practical situations. It is currently a relevant topic, considering the close connection it has between education and industry. Its objective is to solve a specific approach focusing on the search and consolidation of knowledge for its application and, therefore, for the enrichment of cultural and scientific development [3].

Some important considerations about AR are highlighted below:

1) It can not be developed outside of theoretical and basic knowledge, which means that it is based on the results of Basic Research (BR), so that AR is the logical continuity of BR. However, the relationship between AR and BR is biunivocal, because the results of the AR help to rectify and expand the concepts emanating from the BR, thus contributing to the consolidations of a theory. As expressed in [4], many academics carry out the hybrid research, mixing both types of research, due to the need to obtain funds for their investigation, which can be provided by public or private institutions, letting them to test or apply what they have researched.

2) It allows to transform theoretical knowledge into concepts, prototypes, products, processes or services. This implies a close collaboration between the academy and higher education (teachers and students), industry and users. Therefore, there is a need for the participation of the end users and the industry responsible for verifying that it meets the needs.

This work gathers the experience carried out by mechatronic students, which allows them to identify the relationship between the knowledge acquired throughout their career, and an application in a real work environment. Part of the objective of devolving the current research work was to answer the question: "To what extent do the mechatronic engineering students recognize the link between the knowledge acquired in their career and the way they carry out an AR project associated with the solution of a real-world problem proposed by a company or an institution?"

First, the students were presented with a need from a company or institution, which must be solved by applying the knowledge gained throughout their career. After choosing a problem, the objectives were set. Table I shows the general objective and the specific objectives set.

The structure of the paper is as follows. In Section 2, we explain the approach taken to address the work and which projects arose from class. In Section 3, the results are explained and divided between each component of the project. We conclude in Section 4 with a summary of the work.

TABLE I. GENERAL AND SPECIFIC OBJETVIES OF THE WORK.

Main Goal	Determine the extent to which a mechatronic engineer student can manage to identify the relation between the knowledge of their profession and the surrounding environment, by carrying out an AR project associated with the solution of a real-world problem, proposed by a company or an institution.
Specific Objec-tives	1. Apply the RBL approach to develop AR projects 2. Identify the characteristics of an AR from this definition and its differences with an BR. 3. Design, build and test prototypes of mechatronic products that solve specific problems in their area of activity. 4. Promote the management of new knowledge not addressed in classes. 5. Encourage teamwork, so that this leads to the development of a functional mechatronic product, and to the elaboration of the descriptive memory that collects all the information corresponding to its design. 6. Expose the results achieved before a court of professors and experts.

II. METHODOLOGY

The RBL was developed through an AR in the class of "Project of mechatronic engineering", whose essence is precisely the solution of a real-world problem in a given context, seeking the implementation or the use of knowledge received or self-acquired. 13 students participated in this task, which were grouped into two teams at the beginning of the semester, and they had the full semester to complete the project.

TABLE II. PROBLEMS RAISED.

Problem	Research characterization
Tempera-ture measure-ment of stable cattle	Problem situation: problems with measuring the temperature of dairy cattle. Problem: there is no system capable of measuring in real time the temperature of a cow, which allows predicting diseases, stress or their mating season. Object of study: measurement of body temperature of living beings. Field of action: methods to measure the temperature of a dairy cow. Course objective: design, assemble and test a prototype system to measure the temperature of a dairy herd. Task: study of methods to measure body temperature; design prototypes based on image acquisition and processing acquired temperature measurements using thermal imaging cameras; make measurements with the prototype and process the data obtained. Hypothesis: with a system to measure in real time the body temperature of a cow, one can predict the caloric stress, symptoms of disease and the mating season of the animal.
Flow sensor for semi automated milking station	Problem Situation: Problems within the measurement of milk in a milking semi-automatic system. Problem: Lack of a device able to measure constantly the flow of the liquid, with a minimum error of 5%. Object of study: Study of the flow and measurement of fluids. Field of action: Methods to reduce the turbulence in flowing liquids. General objective: Design, mount and test a working prototype of a turbulent fluid flow sensor, with an error less than 5%. Tasks: Study the classical methods to reduce the turbulences on a fluid; design prototypes based on aerodynamic profiles and on the brachistochrone curve; characterize measurements using optoelectronics; measure with different prototypes and process the gained data. Hypothesis: Reducing the turbulence on the fluid will raise the precision and accuracy of the measurement, within a 5% error.

Of the three routes suggested in [9], the second one was chosen, where from a real known problem and an idea-solution based on a theory, a hypothesis is generated. The hypothesis triggers a research process based on experiments, tests and analysis of the results. Each team worked on a different problem, which is shown in Table II.

Both problems were worked on during the time given. The students had freedom to find their own solutions, in order to encourage the development of abilities and skills not seen in class, helping them to gain knowledge in other areas.

III. PARTIAL RESULTS OBTAINED

From the characterization discussed, the partial results obtained in the measurement of the temperature of the cattle are exemplified. Only these results will be explained in detail for conceptualization purposes.

After defining the method to use for the measurement of the temperature of the livestock, considering the economic resources, an approach was determined. The team decided to develop a prototype with cheap components, in a way in which it would show the main idea of the whole project.

A. Camera

Research was done in order to choose an accurate thermographic camera that fulfills the specifications of the project. After a thorough investigation, the Adafruit AMG8833 [5] was chosen, although the Flir E6 [6] is a better option technically, but it is too expensive for this project.

The AMG8833 camera complies with the needs of the project, although it has a poor accuracy of -+3ºC, a maximum reach of 5 meters and a field of view of 60º. Table III was created to show how different the accuracy of the AMG8833 is, compared to other types of temperature sensors. For the camera the maximum measured temperature was considered. Also, a wet simulation was done in order account for the situation when an animal becomes wet when water it is sprayed on it.

TABLE III. TEMPERATURE MEASUREMENTS

Body Part	Digital Themom-eter	Distance	Laser		Camera	
			Dry	*Wet*	*Dry*	*Wet*
Hand	34.4ºC	5 cm			34.5ºC	32.75 ºC
		30 cm	36.1ºC	32.00ºC	33.25ºC	31.25 ºC
Face	35.7ºC	5 cm			35.25ºC	
		30 cm	35.6ºC	34.6ºC	34ºC	
Body	35.8ºC	5 cm			35.75ºC	33 ºC
		30 cm	37.8ºC	32.9ºC	33ºC	32.25 ºC
		1 m	37.9ºC	32.5ºC	31.75ºC	
		3 m	32.2ºC	32.2ºC	35.55ºC	

The camera works with inter-integrated circuits (I2C) communication, which can be connected to a microcontroller. For this case an Arduino was chosen. As the Adafruit has open libraries for Arduino, it facilitates the use of this device. The sensor sends an 8x8 matrix of temperatures, which can be seen in Figure 2, where each number corresponds to a pixel of a picture.

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-- Pixels Test --

[24.25, 23.50, 23.50, 23.50, 23.50, 23.50, 23.75, 23.00,
24.50, 24.25, 24.25, 24.50, 24.75, 24.50, 24.00, 24.50,
25.25, 25.25, 25.25, 25.00, 25.00, 24.75, 24.25, 24.25,
26.00, 26.75, 27.00, 26.75, 27.00, 25.50, 25.50, 24.00,
26.00, 28.25, 27.75, 28.00, 28.75, 28.50, 25.75, 24.50,
25.25, 27.50, 28.25, 29.25, 29.75, 28.25, 25.25, 24.25,
27.75, 27.75, 28.25, 29.25, 29.75, 28.75, 26.00, 24.50,
28.75, 26.75, 27.25, 28.75, 29.50, 26.50, 25.75, 24.75,
]
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Figure 2. 8x8 Matrix example.

Although the sensor does not capture an image, only temperatures, the data was processed on MATLAB to create an image, which is shown in Figure 3. Due to the small number of pixels, the array had to be converted into a larger one. For this, a method called bicubic interpolation was used to create a 32x32 image and improve the quality.

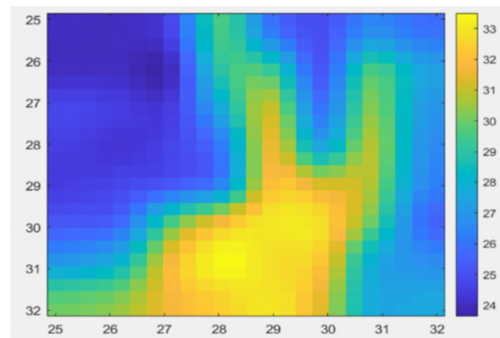

Figure 3. Thermographic image of a hand on MATLAB.

B. Identification System

The project is supposed to be operating in an establishment where there is a large amount of livestock. For this reason, an identification system had to be implemented, in order to identify the cow, in this case, as it gives helpful information to the carer. For identification, a radio frequency identification (RFID) RC522 module was used, but other methods can be used, such as image identification or magnetic sensor. The RFID module has a reach of approx. 5 cm [7]. Although is a short distance, these types of systems can be made so that they reach up to 10 meters, which is enough for projects implemented in the field. These systems identify pre-programmed identification cards that pass through the range of the RFID signal.

C. Mechanism

The location where the project would be placed is in a barn where livestock is kept. For this reason, the idea of mounting the camera with the identification system on a base, which would be held by a movement system involving a band that moves the system back and forth. It is supported by 2 rails. In addition to moving back and forth, the base of the camera can move on the spot 120º to increase the field of view. A 3D model was designed, as shown in Figure 4, before implementing it using specific materials. The materials used to create the prototype were: ABS plastic, wood, steel bars, toothed band, DC motor, servo motors, electric components (H bridge, resistors) and copper cable. The prototype range of motion was under 50 cm.

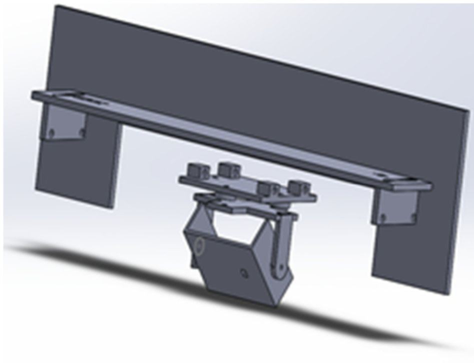

Figure 4. 3D model of the camera mount mechanism.

D. Data system

All the data is saved on a platform where a table of temperatures with their corresponding thermographic images is placed together with the date and time of the measurement. In this way, the end user can go back to past records or look into present ones. MATLAB was used to process the data and save such files into a specific folder in the computer.

E. Prototype

After consolidating all the parts of the system, the final prototype was created. An image of the result is shown in Figure 5.

Figure 5. Final protype of the temperature acquisition system.

As shown in Figure 5, the prototype was constructed at a smaller scale, so it can be tested in the classroom. In order to be tested in a barn, the prototype would need to measure at least 6 meters in length, to fit in the barn structure. For this reason, the team decided to first prove the mechanical and electronic functioning with a smaller size device, as a larger prototype would have the same principle.

IV. Conlusion

The objective of this paper was to allow mechatronic students to relate the acquired knowledge throughout their career, with an AR project to implement a solution for a real-world problem. This was reached through the research done and with the reported results. The RBL approach was applied throughout an entire university semester as part of the course entitled "Project of mechatronic engineering".

Following this RBL approach, solutions were reached as well as some transversal key competences were developed, for example, teamwork, written, presentation skills, and abilities to solve complex problems. In addition to developing competences, the project's team gained knowledge regarding image processing and skills on the use of software for programming and data management, in this case were MATLAB and Arduino. The obtained results allowed the qualitatively evaluation of the students (final grades between 95 and 100), two rubrics were used to grade the written proof and the oral presentation.

The project allowed students to link applied investigation with the research-based learning method, achieving something that most desire, which is to solve problem based on an industry or company needs through an academic approach.

We suggest the following recommendations for the follow-up of the project:

1) Employ project management tools, for example: Wrike, Asana and Flow, in order to ensure a better control of the project phases.

2) Apply a survey to the students, where they state what have they learned, which challenges they have overcome and what area of opportunity they discovered. In the same way, apply other survey to the client, where he can express the level of satisfaction with the problem solution.

3) For the complexity of the problem, the prototype was constructed at a smaller scale, which is yet to be adapted, so it can be placed in a barn.

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References

[1] "Edu Trends: Educational Innovation Radar," (2017), Monterrey: Instituto Tecnológico y de Estudios Superiores de Monterrey, https://observatorio.tec.mx/radar-de-innovacin-educativa-2017/, [retrieved: 02, 2020].

[2] M. Pedaste et al., "Phases of inquiry-based learning: Definitions and the inquiry cycle," Educational Research Review, vol 14, pp. 47–61, 2015.

[3] "Applied Research," (n.d.), Duoc UC, http://www.duoc.cl/biblioteca/crai/definicion-y-proposito-de-la-investigacion-aplicada, [retrieved: 02, 2020].

[4] P. J. Bentley, M. Gulbrandsen, and S. Kyvik, "The relationship between basic and applied research in universities," High Educ, published on line: 25 March 2015.

[5] "Adafruit AMG8833 8x8 Thermal Camera Sensor," (n.d.), Adafruit, https://learn.adafruit.com/adafruit-amg8833-8x8-thermal-camera-sensor, [retrieved: 02, 2020].

[6] "Flir E6 WIFI," (n.d.), Flir, https://www.flir.com.mx/products/e6-wifi/, [retrieved: 02, 2020]

[7] "RC522 RFID Module," (n.d.), Components101, https://components101.com/wireless/rc522-rfid-module, [retrieved: 02,2020]