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Mechatronics Engineering Integrate Project: An Approach in Project-Based Learning with the Subjects of Instrumentation, Control Systems, and Microcontrollers

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ABSTRACT

When discussing integrating projects in classes, we often apply Project-Based Learning (PjBL) techniques. To promote skills, the PjBL methodology subjects students to tasks and challenges to develop a project that connects with their lives outside the classroom or the work environment. During this process, students deal with interdisciplinary issues and take decisions acting alone and in teams. This work aims to present the details of the integrated and multidisciplinary project, applied from 2019 to 2022 in the Control and Automation Engineering course at the Mauá Institute of Technology. During this period, around 40 students per year were analyzed, always from the 4th year of the course, divided into approximately 10 teams per year. The projects were carried out within the subjects of Instrumentation, Microcontrollers, Programming, and Control Systems. The presented results allow for verifying the evolution of the methods as well as the skills developed.

Keywords: Integrative project, multidisciplinary project, control, and automation engineering.

INTRODUCTION

Engineering courses in Brazil, have the characteristic of integrating theory and practice, therefore, interdisciplinarity, research, and extension are fundamental steps for an integral formation of the engineer [1]. A. Ribas Neto, M. Fiorin and T. Dequigiovani [2] comment on the importance of applying projects in building students' knowledge of the technology degrees.

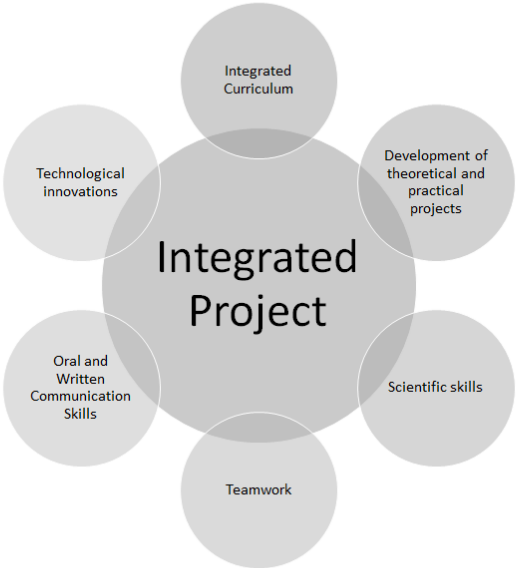
When searching for these courses, it is possible to find a large list of courses that contain integrative projects in their curriculum so that students develop knowledge in an integrated way and help in understanding what each course proposes to offer. C. Cechella Philippi [3], defines an integrative project as an inter and multidisciplinary pedagogical practice that relates the topics and contents taught in the classroom, providing communication between theory and practice of professional performance.

In the Control and Automation Engineering course, the objective of the integrated project is to strengthen the student's theoretical and practical learning, using the knowledge and contents already studied during the course for the development of a technical project, in order, to solve a real industry problem [4]. Some specific objectives of this integrated project can be seen in Figure 1 and are described below:

- integrate the content of the curricular components of the current and previous years.enable the student to develop theoretical and practical projects applied to problem solutions.

- develop the student's skills with the handling and correct application of tools, instruments, and laboratory equipment.
- encourage group work and student integration.
- develop competence in oral and written communication.
- encourage the search for technological innovations in the development of engineering projects.

Figure 1 - Objectives of an integrated project



This work aims to present the details of the integrated and multidisciplinary project, applied from 2019 to 2022 in the Control and Automation Engineering course at the Mauá Institute of Technology. During this period, around 40 students per year were analyzed, always from the 4th year of the course, divided into approximately 10 teams per year. The projects were carried out within the subjects of Instrumentation, Microcontrollers, Programming, and Control Systems.

METHOD

When talking about the integrated project, one of the most applied techniques is Project-Based Learning (PjBL) [5] [6]. Bacich and Moran [7] demonstrate that project-based learning is a methodology in which students engage with tasks and challenges to solve a problem or develop a project that is connected to their lives outside the classroom or the job market and during the process, the students deal with interdisciplinary issues, make decisions and act alone and in teams.

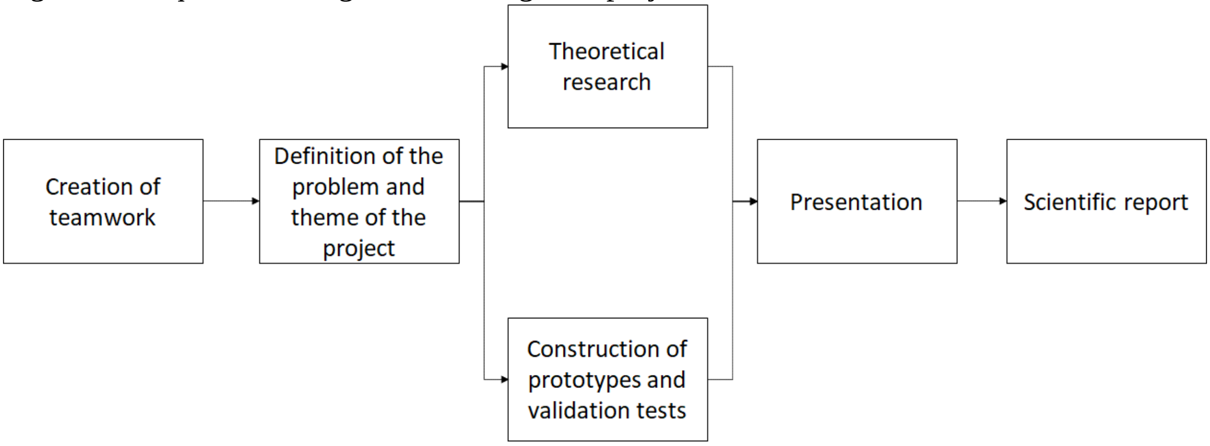
Utilizing PjBL concepts [8], the integrated project applied to the subjects of Instrumentation, Microcontrollers, Programming, and Control Systems, was divided into stages, to facilitate students' understanding and improve the dynamics of application and feedback on the results obtained. The division was made in 6 stages, being:

1. Creation of teamwork.
2. Definition of the problem and theme of the project.

3. Theoretical research.
4. Construction of prototypes and validation tests.
5. Oral and practical presentation.
6. Written a scientific report.

The stages are not entirely sequential, being organized as shown in Figure 2:

Figure 2 - Sequence of stages of the integrated project



Each of the stages is extremely important for the objectives of the integrated project to be achieved. The entire project is developed during the classes of the subjects of Instrumentation, Microcontrollers, Programming, and Control Systems, and the professors mediate within their specialty and insert content from other subjects, to connect the greatest number of learned contents.

At the end of each stage, it is important to provide feedback on the development and alignment of project expectations [9]. Each of the stages taken to carry out the integrated project will be described below.

Creation of the teams

At this stage, the students are invited to create teams of at least 02 and at most 05 students. This division should start with the students, each team is responsible for the best organization of the members that make up the groups.

Definition of the problem and theme of the project

Before the teams define the themes, the students were introduced to the minimum requirements of the project, which are:

- have a real application proposal, for a domestic or industry problems.
- the sensors used in the project must read analog signals.
- the outputs (actuators) could be both digital and analog.
- must have a HMI (human-machine interface) created in a PC that uses serial protocol for reading the sensors signal.
- have a measurement indicator.
- develop from a data logger.

- show validation of sensor measurements using a calibrated measuring instrument.
- present the calculations and dimensioning of the project.
- present a detailed technical drawing of all components used in the project.

Based on minimum project requirements, the teams define which topics are addressed and which problems each group will deal with.

Theoretical research

In this stage, students must carry out theoretical research about the problem to be solved, searching for other works that address same problem looking for sensors, controllers, and actuators that can be used.

It is important to guide students during this stage so that theoretical production does not become a handout with a list of equipment definitions, but rather a reference material for the bibliographical research used as the basis for the work produced.

Construction of prototypes and validation tests

This stage takes place in parallel with the stage described in the item of Theoretical research. At this time, students build prototypes to test the hypotheses that solve or not the problems defined in the item Definition of the problem and theme stage of the project.

It is important that at this stage, the professors guide the groups to develop structured tests based on the objectives that the works want to achieve, providing statistical analyzes with a greater conclusive basis. At this stage, the groups must also document the entire process, showing the construction and evolution of the project to be presented.

Oral and practical presentation

The projects are presented in a seminar format, with a maximum time of 10 minutes, where they should include the theoretical explanation of the work (research, design, tests, and results) as well as the practical demonstration of the functioning of the prototype.

This presentation is made for all groups and the professors of the four subjects (Instrumentation, Microcontrollers, Programming, and Control Systems) monitor and evaluate the works. It is also important that the other groups can also discuss the work presented, to develop everyone’s critical thinking.

Present the project developed in a scientific report format

To develop students' writing skills, a scientific report must be delivered at the end of the project. This project follows the same model of undergraduate thesis of the Mauá Institute of Technology, which makes the students already have contact in a preliminary way to the use of the document, which facilitates the development of the thesis in the last year of the undergraduate.

RESULTS AND DISCUSSION

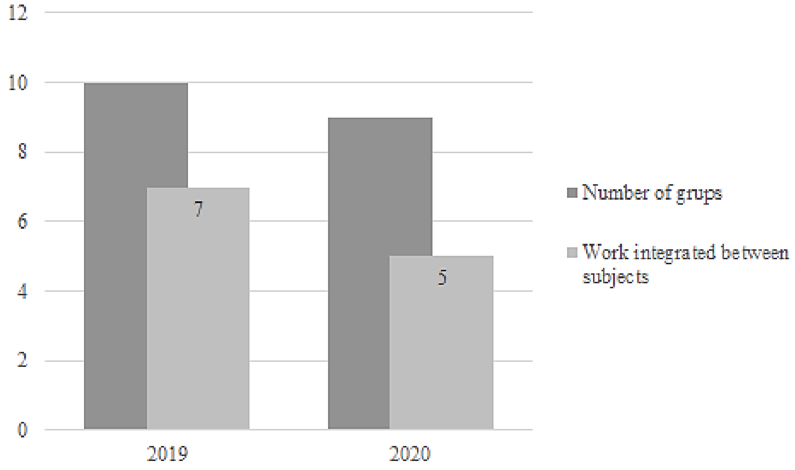
During the period from 2019 to 2022, the integrated project applied in the Control and Automation Engineering of the Mauá Institute of Technology underwent an improvement process, for students to obtain a greater perception of value when exposed to practical projects. This improvement process took place in 3 cycles, the first cycle in 2019 and 2020, the second cycle in 2021, and the third cycle in 2022. During the period, around 40 students per year were analyzed, always from the 4th period of the course, divided into approximately 10 teams per year.

First cycle: 2019 and 2020

In the first project application cycle, students had practical completion projects for each of the four subjects (Instrumentation, Microcontrollers, Programming, and Control Systems), however, each of the subjects was in charge of defining the period in which the project would take place, the technical and team-building requirements, and evaluation methods. Therefore, it was up to the students to manage how the projects would take place and, if possible, the integration between some or all the subjects involved in the projects, interdisciplinarity is not a mandatory item for any of the projects.

With this scenario in mind, and bearing in mind that in 2020 we went into isolation due to the COVID-19 pandemic, the graphs shown in Figure 3 show the number of students and groups that worked with an integrated project in at least 2 subjects. In 2019, 38 students were analyzed, divided into 10 teams, and in 2020, 30 students were analyzed, divided into 9 teams.

Figure 3 - Comparison between the number of groups and groups that worked with an integrated project in the first cycle.



As examples of projects that integrated some subjects can be highlighted, the project of a sensor for monitoring heartbeat (integration between Instrumentation and Microcontrollers), the development of a garden humidity monitoring system (integration between Instrumentation, Microcontrollers, and Programming), and the development of a swimming pool temperature control system (integration between Instrumentation, Microcontrollers, and Control Systems).

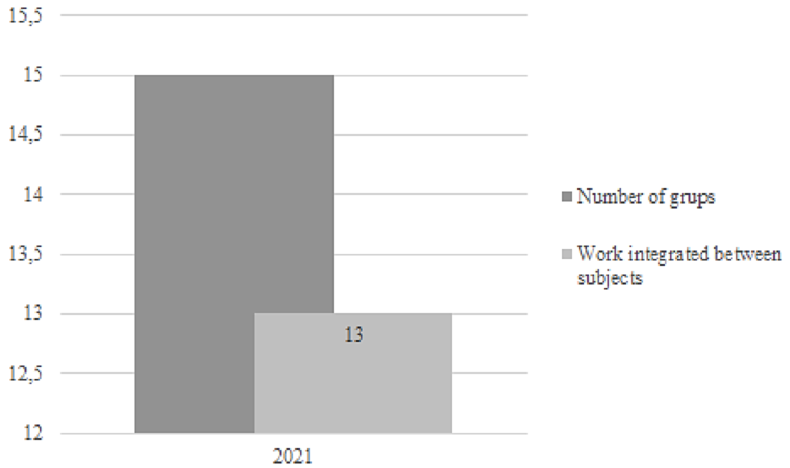
As not all subjects started the project in the same period, Programming started in August, Instrumentation and Microcontrollers in October and Control Systems in November, with requirements that often did not collaborate with the integration proposal, and in 2020 the COVID-19 did not allow attending the laboratories in person, the students' option for the integrative project became less attractive and, therefore, there was a low adherence to the construction of projects integrating the subjects.

Second cycle: 2021

In the second cycle of the project application, in 2021, to adjust the dynamics of the projects of the subjects and make them integrated projects, common minimum requirements for projects within the subjects were stipulated. The practical projects of completion of the subjects continued to occur, and the integration between them was not mandatory.

In this second cycle, 47 students were evaluated, and divided into 15 groups. The choice of groups and topics covered was the responsibility of the students and the mediation by the professors. Figure 4 presents the number of students and groups who worked on an integrated project in at least 2 subjects.

Figure 4 - Comparison between the number of groups and groups that worked with an integrated project in the second cycle.



Two teams chose not to carry out the integrative project, and when asked why they chose it, the students said they were afraid of not being able to achieve a good evaluation in the project and failing in two subjects.

Examples of projects that were part of some subjects can be highlighted, the development of a capacitive level sensor of a LabVIEW reservoir (integration between Instrumentation and Microcontrollers), and the development of a turbine flow monitoring system and tachometer (integration between Instrumentation, Microcontrollers, and Programming) and development of a portable refrigeration system (integration between Instrumentation, Microcontrollers, and Control Systems). In addition to the alignment of technical requirements, the evaluation was applied through rubrics, the same rubric for all subjects in which the project was presented. Table 1 presents the evaluation heading.

Table 1 - The first revision of the evaluation rubric

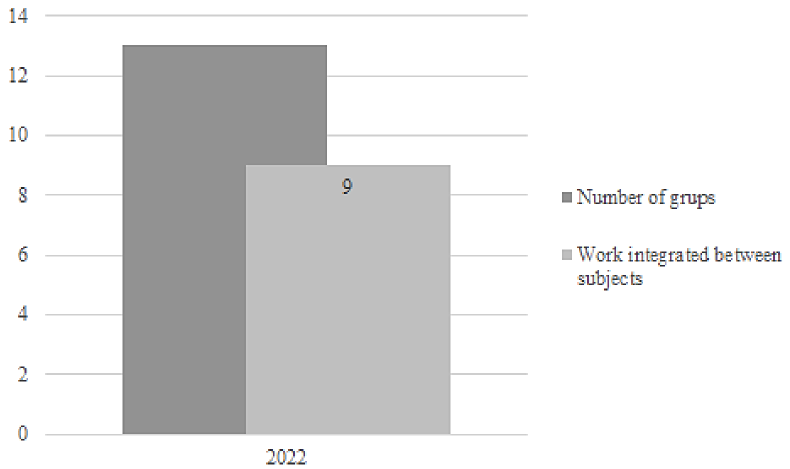
Description	0 points	1 point	2 points	3 points
Implementation of circuits in simulator	Failed to implement the circuits for the most part.	Managed to implement most of the circuits, but many interventions were necessary.	Managed to implement most of the circuits, with few corrections.	Managed to implement all the circuits, practically autonomously.
Theoretical concepts in simulation	Failed to apply the theoretical concepts and the simulation did not provide a correct result, for the most part.	Failed to apply the theoretical concepts, but most of the simulations showed correct results.	Failed to apply the theoretical concepts, but the simulations showed correct results.	Managed to apply the theoretical concepts and the simulations resulted in correct results.
Result interpretation	Don't interpret the results in most or all of them.	Interpreted a few results.	Interpreted part of the results.	Interpreted all results.
Project development	The practical project was not developed in any part.	The project was developed partially, lacking a conclusion regarding the operation of the circuit.	The project was developed partially, presenting the circuit definition processes.	The project was fully developed, presenting all the steps in detail.
Project presentation	Inadequate presentation, without minimal information about the development of the work and non-functional final circuit.	Presentation with little information about the development of the project and the final circuit partially works.	Presentation with the necessary information, but the final circuit partially works.	Presentation with all the necessary information and final circuit in full operation.
Finalization of the Project	The inadequate report, without following formatting, and little information about the project.	The report is not complete, and the final circuit partially works.	The adequate report, but the final circuit partially works.	The adequate report and final circuit are in full working order.
Participation of team members	The work was carried out with the contribution of a small part of the team, or it was not carried out at all.	The work was carried out with the contribution of only half of the team.	The work was carried out with the contribution of most of the team members.	The work was carried out with the contribution of all team members.

When asked students about the perception of the importance of integration between the subjects and the use of the same evaluative instrument for the projects, they reported that an important point is to observe the application of the knowledge of various subjects in a single project, also commented that decreases using a single project for various subjects decreases the load at the end of the period and on the use of rubrics, students commented that with the heading they can know the evaluative criteria during the project development process which helps to manage to learn.

Third cycle: 2022

The third cycle of the integrated project took place in 2022, where some more modifications were made to the scope to ensure that all teams completed the subjects with projects integrated into at least two subjects. To this end, integrating instrumentation and microcontrollers disciplines was placed as a mandatory item and optionally integrated with programming and control systems. 46 students were evaluated, and divided into 13 groups, the choice of groups and topics covered was the responsibility of the students, as well as how they would carry out the integrated project. Figure 5 presents a graph with the number of students and groups that worked on an integrated project in more than 2 subjects.

Figure 5 – Comparison between the number of groups and groups that worked with an integrated project in the third cycle.



Examples of projects that were part of some subjects can be highlighted, the Aero-stabilizer Project (integration between Instrumentation, Microcontrollers, and Control Systems) presented in Figure 6, the electronic drums project (integration between Instrumentation, Microcontrollers, and Programming) presented in Figure 7, and ball and pipe control system project (integration between Instrumentation, Microcontrollers, and Control Systems) presented in Figure 8.

In addition to the alignment of technical requirements, the evaluation was applied through rubrics, the same rubric for all subjects in which the project was presented. Table 2 presents the evaluation heading.

Table 2 - The second revision of the evaluation rubric

Description	0 points	1 point	2 points	3 points
Theoretical concepts in the project	Failed to apply the theoretical concepts and the operation did not provide a correct result, for the most part.	Failed to apply the theoretical concepts, but most of the circuits showed correct results.	Failed to apply the theoretical concepts, but the operation showed correct results.	Managed to apply the theoretical concepts and circuits presented with correct results.
Project development	The practical project was not developed in any part.	The project was developed partially, lacking a conclusion regarding the operation of the circuit.	The project was developed partially, presenting the circuit definition processes.	The project was fully developed, presenting all the steps in detail.
Circuit implementation	Failed to implement the circuits for the most part.	Managed to implement most of the circuits, but many interventions were necessary.	Managed to implement most of the circuits, with few corrections.	Managed to implement all the circuits, practically autonomously.
Programming	Failed to program the circuits for the most part.	Managed to program most of the circuits, but a lot of interventions were necessary.	Managed to program most of the circuits, with few corrections.	Managed to program all the circuits, practically autonomously.
Result interpretation	Don't interpret the results in most or all of them.	Interpreted a few results.	Interpreted part of the results.	Interpreted all results.
Project presentation	Inadequate presentation, without minimal information about the development of the work and non-functional final circuit.	Presentation with little information about the development of the project and the final circuit partially works.	Presentation with the necessary information, but the final circuit partially works.	Presentation with all the necessary information and final circuit in full operation.
Integration between subjects	The project doesn't integrate the subjects.	The project was developed in a partially integrated way, but with fault.	The project was developed in a partially integrated way without fault.	The project was developed in an integrated manner.
Participation of team members	the work was carried out with the contribution of a small part of the team, or it was not carried out at all.	The work was carried out with the contribution of only half of the team.	The work was carried out with the contribution of most of the team members.	The work was carried out with the contribution of all team members.
Project documentation	The inadequate report, without following formatting, and little information about the project.	The inadequate report, without formatting, but with information about the project.	The adequate report, but with little information about the project.	The adequate report, with all the information about the project.

Figure 6 - Aero-stabilizer Project.

Figure 7 - Electronic Drums Project.

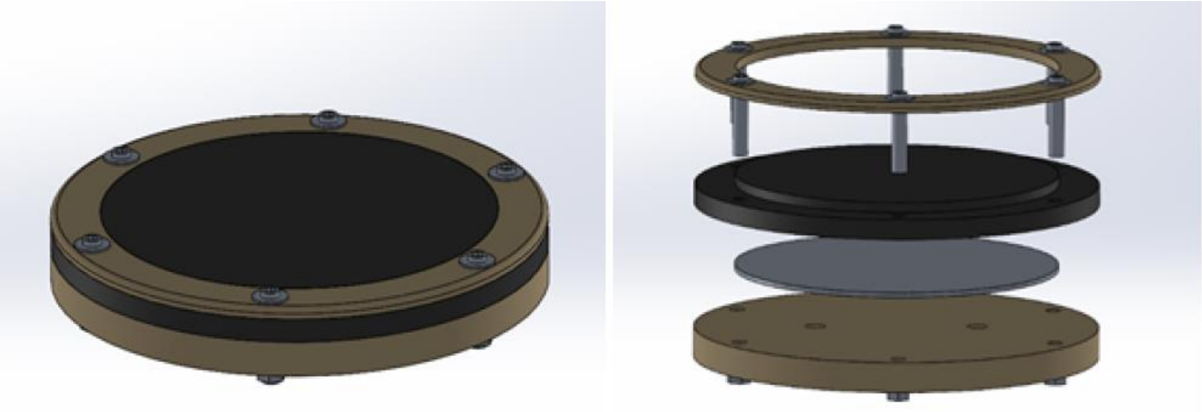


Figure 8 - Ball and pipe Project.

At the end of the project, the students were asked what their general perception of the development of the project was. In the general conception of the students, the project developed a differential for professional training, as it unites teamwork, and integration between different subjects, in addition to facilitating the understanding of theoretical concepts when applied in practice.

The students also commented on the possibility of developing skills in problem-solving, through theoretical research and the application of their already acquired knowledge. Integrated projects exist not only for teaching and applying methodologies studied in the course but also for the search for technological innovations.

CONCLUSION

In addition to the integrated project, it collaborates to build the skills and competencies of graduates, it can also be used to diagnose other factors, such as, for example, the student's level of knowledge, evaluation of the content addressed in other curricular and even extracurricular subjects, including the curriculum reformulation, methods and theory and laboratory classes.

It could also be noticed that some students have a greater affinity for the execution of the practical project, however, they have low resourcefulness in the elaboration of the theoretical report or even in the oral presentation.

From a general point of view, the integrated project proved to be a differentiated means of learning for students, offering the development of their skills and competencies, and fulfilling their objectives. For the professors, it was a means of diagnosing the level of teaching and providing further discussion and improvement.

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