Engineering Solutions to Real Problems with Interdisciplinarity in a Traditional Curricula

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Abstract*—This complete work on innovative practices presents a proposal for a framework applied in an engineering discipline based on hybrid teaching and active methodologies, carefully planned to allow students to contextualize their essential content added to the social impact of their profession. This proposal seeks to guarantee the possibility of assimilating learning between lines and between years of study, guaranteeing connectivity between the teaching teams of the interdisciplinary faculty, between the lines of the curriculum, and between students, inside and outside their formal studies and the classroom. In this way, we provide not only the development of technical skills but also contemplate one of the significant challenges in engineering education, which is the development of socially relevant engineering curricula, thus strengthening the intrinsic motivation and adaptability of the student. In the face of the ongoing transformations in the engineering field - especially considering the rise of Industry 4.0 - professionals in this area must get an inter and transdisciplinary education, in close touch with society and industry needs. This calls for educational practices that stimulate entrepreneur development, dynamical skills, and traditional technical knowledge. In this work, we propose the 4D CV framework based on hybrid teaching and new trends in teaching and learning based on active methodologies, seeking to train a future professional who acts as an active agent in society, capable of facing the challenges of Engineering in the 21st century. We create learning environments that allow for (i) the development of capacity and motivation for teamwork in a technical, multi, and interdisciplinary way; (ii) a creative environment aiming for a comprehensive education along with entrepreneurial spirit and ability to innovate; (iii) reflection and discussion that favor independent critical thinking; (iv) actions that strengthen the university's relationship with the local community allowing closer relation with society and the productive sector. The proposed framework was the subject of a case study applied in the discipline of Curricular Integration Activities IV, of the undergraduate course in Automation Engineering of a Federal University of Brazil, where the technique of the Discourse of the Collective Subject (DCS) to capture the impression of those involved in the study (students, teachers and partner companies). It was possible that the practices of the proposed curriculum project could provide students with inter and multidisciplinarity in their learning process. In addition, students have been motivated in the face of involvement with the needs of society, achieved through practice in an innovative project in which the challenge was based on the real pains/demands/needs of a real startup company, formed by graduates of the course itself, already established in the market. We can thus conclude not only the tremendous innovative potential of our curricular proposal in the face of the significant challenges in engineering education but also its innovative character in approaches to higher education in Brazil.

***Index Terms*—enginnering, curriculum, extension, project**

I. Introduction

Incorporating real-world problems into engineering curricula is essential for bridging the gap between theoretical knowledge and practical application. By providing students with authentic and relevant problems, educators can create an environment where theoretical concepts can be applied in real-life scenarios. This approach enhances students' problem-solving skills and prepares them for the challenges they will face in their future engineering careers [1].

Traditional curricula can only handle some of the demands of the modern world for the current engineer profile. According to [2], the critical issues that need to be addressed can be summarized as follows:

- Engineering curricula are excessive focused on engineering science and technical courses without providing sufficient integration of these topics or relating them to industrial practice. Programs are content-driven.
- Current programs do not provide sufficient design experiences to students.
- Graduates still lack communication skills and teamwork experience, and programs must incorporate more opportunities for students to develop these.
- Programs need to develop more awareness amongst students of the social, environmental, economic, and legal issues that are part of the reality of modern engineering practice.
- Existing faculty lack practical experience and cannot adequately relate theory to practice or provide design experiences. Present promotion systems reward research activities and not practical experience or teaching expertise.
- The existing teaching and learning strategies or culture in engineering programs is outdated and needs to become more student-centered.

The modern issues faced today cannot be solved by just looking at them from a technical perspective. Instead, we need to consider them within the larger context of society and take a more holistic approach to problem-solving. In order to do so, we need to adopt different curricula, methodologies, and learning processes. Addressing complex problems requires collaboration and involvement of people from different disciplines, as individuals working alone cannot solve them. In such cases, problem-based learning (PBL) and project-based studio pedagogies provide appropriate physical environments that enable problem-solving and engage intrinsic and extrinsic motivations. These interactive learning environments help to solve complex issues by encouraging collaborative approaches [3].

PBL approaches have limitations due to the educational and institutional frameworks within which they operate. PBL is typically part of the broader traditional curricula, which can include various units or courses within a degree program offered by an educational institution. When applied to traditional approaches without a curricula-integrated strategy, it limits students' learning experiences concerning the complexity of problems encountered and the authenticity of the practice environment in which the students are situated [1].

The undergraduate courses of the Center for Computational Sciences (C3) of the Federal University of Rio Grande - FURG include a shared discipline in all periods except the last one: Curricular Integrating Activity (in portuguese "Atividades de Integração Curricular" (AIC)). Besides being a discipline, its proposal foresees an environment for integrating the content of all disciplines, but not limited to, in project format. Within this environment, students could develop skills usually developed by those involved in research projects. The participation of students in the scientific initiation of these projects was not a mandatory activity in the curriculum, and it was restricted to a few privileged ones. AIC is in the curriculum of Automation Engineering, Computing Engineering, and Information Systems since 2009.

AIC has an interdisciplinary nature, such as proposed by [4], i.e., individuals in interdisciplinary teams learn from others' perspectives and produce work in an integrative process that would not have been possible in a mono-disciplinary setting. At least in theory, the result is that participants emerge from such interactions speaking "one language." It is also mandatory that the interaction between fields of expertise requires some level of integration among those fields.

This notion is proposed in a comparison context with multidisciplinarity and transdisciplinarity. By contrast, multidisciplinary interactions are less likely to employ integrative processes, and the individuals involved do not necessarily learn from other disciplinary perspectives. Multidisciplinarity can be characterized as a combination of disciplinary components, whereas interdisciplinarity requires methodological or conceptual synthesis to deepen knowledge and skills. Transdisciplinarity takes this synthesis a step further by starting from two or more disciplines and applying their knowledge and skills to real-world problems or projects in collaboration with stakeholders outside the university, thus aiming to enhance the learning experience [4].

During this time, AIC receives much criticism from teachers and students, including:

- the absence of an integrated view between the periods in a way that students could accompany an evolution process;
- The proposed projects by teachers had minimal engagement with reality;
- AIC follows the same assessment calendar so that the project deliveries coincide with exams of other disciplines, and students normally prioritize traditional disciplines.

In this paper, we describe a proposal for AIC reformulation based on the following requisites:

- to become AIC an environment for managing real-world problems, where students, with the advice of a teacher, can define a problem, specify, develop, and validate a solution, including gathering the necessary resources to generate this solution.
- solutions must present a system context, integrating knowledge from different disciplines and people with diverse profiles;
- to permit developing social skills for working in teams, where teams include colleagues developing the solution and clients describing the solution demands. This exposes students to a broader and more complex array of experiences and enables them to confront social and ethical issues in everyday practice.

This paper describes an innovative practice proposed in AIC IV that was applied in the fourth period of Automation Engineering undergraduate course at C3/FURG. A modern team-based environment inserts students into a real-world engineering context driven by Conceive-Design-Implement-Operate (CDIO) complex value-added engineering systems. The goal is to propose a framework model and its management mechanisms based on student-centered international methodologies and, in its context, explore knowledge, creativity, innovation capacity, and entrepreneurship. The proposal can be understood by the following specific goals:

- to create an opportunity for developing the student's capacity and satisfaction in working in teams in a technical and interdisciplinary way.
- to strengthen the teaching environment, offering a creative space with a wider and more profound view, capable of fostering the entrepreneurship spirit and innovation capacity.
- to create a space and time for reflecting and discussing through critical and autonomous thinking, permitting a better involvement with society and the industrial sector.
- to promote actions approximating the university with the community, in a close relationship between academic knowledge and society's demands.

II. Background and the Changing Context

This section describes the institutional context in which this proposal arises, including the theoretical background that supports it.

FURG is the southern public university in Brazil, located in Rio Grande, a medium city in the Rio Grande do Sul state. It is situated on the shores of the Lagoa dos Patos, a large lagoon connected to the Atlantic Ocean. With over 200,000 people, Rio Grande is one of the oldest cities in Brazil, founded in 1737. The city has historically been an important port, serving as a gateway for trade and commerce between Brazil and other countries. Its strategic location has contributed to its growth and development as a hub for maritime activities, including shipbuilding, fishing, and port operations. The Port of Rio Grande is one of the busiest ports in Brazil, handling a significant portion of the country's exports and imports.

The university has an academic system based on traditional models. The main curricular component available is the discipline. According to [5], the undergraduate courses have the discipline as fundamental unity and understood as a study and activity set in a well-defined field of knowledge corresponding to a program developed in a minimum workload previously planned. Therefore, even obligatory components such as curricular internship and Graduating Project [1] are framed as disciplines in the last period of the course. In this case, those activities have entries in the scheduled program, even managed by the student and a mentor professor. There is an exception for this conception that considers Complementary Activities in the formal curriculum, where can be considered all the activities executed by the student during the course beyond the obligatory disciplines. Directive No 64/1997 [2] of the Teaching, Research and Extension Council (COEPEA)

Due to the limitation of using discipline as the sole resource for curriculum deployment, specific calendars, schedules, and assessment constraints should follow a pre-planned program. Additionally, the various disciplines impose a competition for the student's time, as each discipline can take 25 to 30 hours per week.

The university is organized by academic units responsible for a specific knowledge area. The Center for Computational is responsible for computing and three undergraduate courses: Automation Engineering, Computing Engineering, and Information Systems. The course's curricula have some disciplines in common, such as those of a mathematical and physics nature. The engineering curricula strongly emphasize these instrumental contents to support a view based on building system models. On the other hand, formal curricula find limitations in the institutional framework to include aspects such as interdisciplinary activities, with a problem-solving characteristic involving multiple actors dealing with real-world engineering problems, including project management competencies. The consequence is knowledge fragmentation and the need to integrate theory and practice.

Hereafter, we refer to interdisciplinarity such as [6], i.e., settings that enable iterative processes of defining and redefining problems in more complex and often "real-world" settings, pushing the participating researchers to create new knowledge by crossing disciplines and paradigms and examining the existing knowledge and approaches through a new lens. The participants must agree on a joint focus and standard methodologies and tools, adding complexity to the collaborative processes from one researcher joining another discipline to large groups of disciplines learning to communicate and collaborate in a joint effort.

To address these limitations, Curricular Integrating Activities (AIC), a discipline included in each period of the undergraduate courses, was created. The goal was to create an interdisciplinary environment with a project-based learning approach. The discipline is not offered in the last year of each course; once during this period, there is a mandatory activity named the Graduating Project for addressing those aspects.

AIC was created based on experience with students who live scientific initiation and participate in research projects. These students informally developed soft skills such as communication, collaboration, working in teams, problem-solving capabilities, time management, and others. They also work with state-of-the-art issues, improving their knowledge about the field. Since this activity was not mandatory in the curriculum, this experience was limited to a few privileged students.

Once it was inserted into the curriculum as a discipline, AIC occupied two hours in the course's weekly schedule, coordinated by two teachers. During ten years in the curriculum of the three courses, it accumulated a lot of criticism from both teachers and students to know:

- Each teacher had its specific methodology for the activities accompaniment. Some described a problem, defined some checkpoints during the year or semester, and evaluated a final delivery. Some teachers described a problem and only expected a final delivery at the end of the period. Some teachers assigned the problem definition as part of the process.
- Most projects were limited to the period discipline scopes. The consequence was the proposition of projects without connection with real-world problems and integration with society's demands.
- Without a clear definition of the discipline, some teachers use it to complement classes of other disciplines.
- Once there was a fixed time in the students' schedule for the discipline, shared with the other disciplines of the period, it was common for some communication problems. Some students expected traditional classes in the time scheduled for discipline, generating complaints about it. When defining an accompaniment based on checkpoints, some students considered only the final delivery important and did not present evidence of the development process in the project. These situations created some frustration among teachers since the goals were not fully reached.

The proposed problem to be addressed was how to include aspects of real-world engineering problems approached in an interdisciplinary project that mitigates the constraints of the university academic system based on disciplines. We define three main components for the framework proposed: a project-based environment, an adapted schedule for the project activities concurrent with the other period discipline, and student training on the following issues: design thinking, entrepreneurship, and soft skills.

[1] It is a project planned and executed by the student in the last period of the course that is requisite for its graduation.

[2] https://conselhos.furg.br/deliberacoes/coepe/plenario/1997/deliberacao-064-1997

The fundamental in this proposal is the interdisciplinarity aspect since it can be justified from three main perspectives [7]: (i)in an academic view, interdisciplinary competence promotes a holistic view of theory and knowledge development; (ii) regarding the market-driven view, projects, and tasks for the future workforce are becoming more complex. Moreover, interdisciplinarity is highly associated with innovation; (iii) finally, in a view toward critical consciousness regarding the sustainability development goals, the development of students' interdisciplinary competence is needed to address urgent problems, also called the "grand challenges" of our time. These complex problems cannot be solved within one discipline. Therefore, education must support students' collaboration abilities across disciplines, facilitating interdisciplinary competence.

The project-based learning goal leads to producing a final artifact, which can be a product, a service, a project, or a model, including documentation. The product results from a process integrating plausible solutions based on collated empirical evidence and the criteria applied to select the most suitable solution [8].

The alternative to project-based learning is problem-based learning. A project usually has a broader scope and may encompass several problems. While acquiring new knowledge is more important than the final solution in problem-based learning, project-based learning emphasizes applying or integrating the knowledge rather than acquiring it. In project-based learning, the end product is the central focus of the assignment, and completing the project primarily requires applying previously acquired knowledge [8]. The framework proposed here is in a context with other disciplines working with knowledge as the primary focus. The final product is relevant since the process includes interaction with real-world demands from a startup. Also, the problem definition that guides the development of the final product must be considered in this process.

Including interdisciplinarity in the education process means addressing soft skills development that complements the students' technical and analytical capabilities. Soft skills are non-technical abilities required in a specific employment setting that enable someone to deliver information or services to customers and co-workers, work effectively as a member of a team, learn or acquire the technical skills necessary to perform a task, inspire the confidence of supervisors and management; and understand and adapt to the cultural norms of the workplace [9]. For an engineer, it includes an ability to function on multidisciplinary teams, an understanding of professional and ethical responsibility, an ability to communicate effectively, and the broad education necessary to understand the impact of engineering solutions within a global, economic, environmental, and societal context; a recognition of the need for and an ability to engage in lifelong learning; and a knowledge of contemporary issues [10].

Complementary to soft skills, demands from the 21st century include aspects of design thinking and entrepreneurship. According to [11], entrepreneurship is an innovative process through which entrepreneurs identify and exploit business opportunities by allocating resources and creating value. It has particular relevance for the technological sector, contributing to job creation, economic growth, and competitiveness, unlocking personal potential, and providing a focal point for many local communities. Furthermore, it has been increasingly recognized as a significant driver of economic development [12]. Creating an entrepreneurship-simulated, realistic environment allows the student to construct an experience about what it means to be an entrepreneur. It includes the process, knowledge, and skills necessary for starting a new business, emphasizing writing and speaking skills, and aims to improve the broader business, communication, and management skills that graduates need to succeed in starting a business enterprise [13].

Design is a central activity in engineering, and it synthesizes the capacity to integrate knowledge into a specific solution for social needs. According to [14], engineering design is a systematic, intelligent process in which designers generate, evaluate, and specify concepts for devices, systems, or processes whose form and function achieve clients' objectives or users' needs while satisfying a specified set of constraints. The design thinking approaches are characterized by the skills necessary for a good designer, including (i) tolerating ambiguity that shows up in viewing design as inquiry or as an iterative loop of divergent-convergent thinking; (ii) maintain sight of the big picture by including systems thinking and systems design; (iii) handle uncertainty; (iv) make decisions; (v) think as part of a team in a social process; and (vi) think and communicate in the several languages of design. Design projects can be used to motivate and integrate learning, and cornerstone project-based courses are also seen as a means to enhance students' motivation and their retention in engineering, in part because they introduce engineering content and experience early in the curriculum, in part because they also put first-year students into direct contact with engineering faculty [15].

Other external factors motivated changes in the curricula of those undergraduate courses that have strong relationships with this proposal: (i) the legal exigence for inserting extension activities in the undergraduate courses; (ii) the updating of the National Curricular Guidelines for Engineering Courses in Brazil [5].

The Education National Plan (in Portuguese "Plano Nacional de Educação") (PNE) target 12.7 - PNE 2014 - 2024 foresees including extension in the curriculum of all undergraduate courses in Brazil, demanding strategies of higher education institutions in Brazil for effective implementation. However, implementing this target has been a challenge because there is a lack of more precise guidelines on a national scale to orient this process. Including extension in the curriculum of all undergraduate courses in Brazil is part of the university's in-dissociability between teaching, research, and extension. It is an effort to establish the necessary university connection with society, detaching its role and the social relevance of teaching and research. The extension is a process that generates a university's commitment to society. Inserting extension in curricula means considering mechanisms that enable a dialogue between disciplinary knowledge and more abroad questions in society. In this sense, university extension must be interprofessional, interdisciplinary, and intertransdisciplinary. This conception approaches the student of society's demands and strengthens a citizenship education. It is also a place for recognition and acceptance of other persons and diversity.

The National Curricular Guidelines for Engineering courses were updated in 2019, and courses nationwide had three years to respond to the changes. The previous guideline, from 2002, was highly based on content and the desired professional profile without considering methodological aspects about how to link these two aspects.

The 2002 DCNs established the integration of engineering knowledge and its applicability through a course final project, the obligatory internship, and complementary activities, with these last two activities as a means to interact with the practice of reality. Also, it offered means for curricular flexibility defining contents only to initial blocks (basic and professional), permitting each institution to define the last block (formation) according to the desired professional profile [16]. Before this DCN's, the courses followed the idea of curriculum as a curricular grid with pre-defined disciplines formalizing the course structure.

A movement coming from the labor market named *Bussinen Mobilization for Innovation* (in Portuguese "Mobilização Empresarial para a Inovação") (MEI) organized by the National Confederation of Industry (in Portuguese "Confederação Nacional da Indústria") (CNI) started the discussions about a DCN updating in 2009. This movement and the Brazilian Association for Engineering Education led nationwide discussions, resulting in the 2019 update. According to [17], the 2019 DCNs, Resolution CNE/CES n^{o} 2/2019 [18], have as the primary focus an entrepreneurial education with less focus on social interests. It reflects the market understanding of necessary competencies in a more flexible professional profile without political and cultural aspects. The main change is a focus on developing competencies and no more a focus on content. The new DCN lists content set only for a basic module, leaving the course to decide on professional and formation module contents. In this sense, the DCN imposes that PPCs must present the elements to guarantee the competencies development defined in the desired professional profile.

In summary, a theoretical framework was designed to contemplate an interdisciplinary environment within a traditional discipline, including aspects of project-based learning, demanding soft skills with training on entrepreneurship and design thinking. This framework is presented in the next section.

III. Methodology

Given the institution's constraints on the academic system and the features necessary to address interdisciplinary aspects in engineering curricula, we developed a framework to be applied in the AIC discipline. In addition to the goals discussed in the previous section, it also aims to provide an environment for assessing the necessary resources to scale this solution at the curriculum level.

This framework, named CV 4D, a four-dimensional framework, aims to advance and improve the education process for Automation Engineering students, described in Fig. 1. Given that traditional classroom practices have remained unchanged for centuries, our challenge was implementing a paradigm shift that could address the new demands of the world and society in educating our students. To achieve this, we developed a structure based on international, student-centered methodologies that consider their environment and reality while leveraging their knowledge, creativity, and capacity for innovation and entrepreneurship. This framework focuses on technical knowledge and aims to develop the necessary soft skills for professionals to become entrepreneurs, execute ideas and new actions, and be active contributors in the workplace, whether as employees, self-employed individuals, public servants, or business owners.

In our pursuit of innovative approaches, we analyzed engineering curricula from universities such as SUTD, DELFT, UCL and CSU, which, based on the 2018-2019 MIT report, are considered references in training the engineers of the future [19]. From these analyses and a profound reflection on our current practices, we developed our 4D framework proposal, which comprises different dimensions designed to engage students dynamically and attractively.

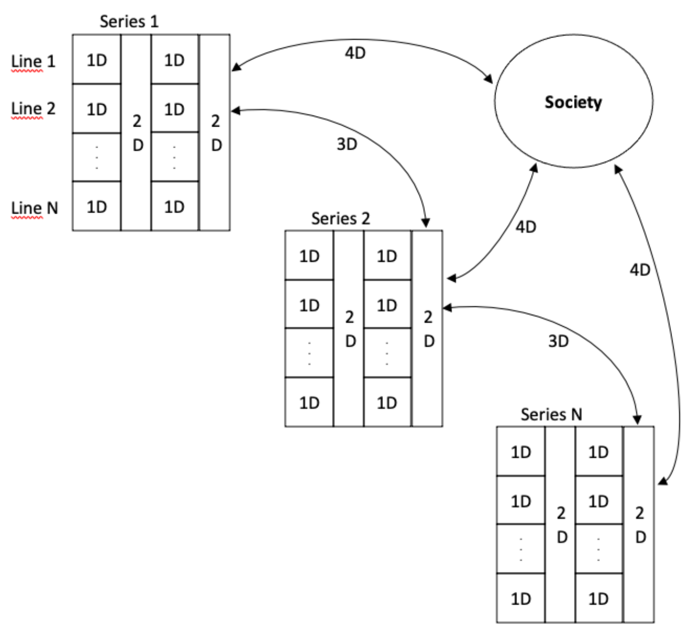

Fig. 1. 4D curriculum proposal - CV 4D

Regarding Dimension 1D, we have knowledge streams such as Exact Sciences or Mathematics (Calculus, Algebra, Discrete Mathematics, etc.), a stream involving Entrepreneurship and Innovation, or even a stream of Humanities knowledge (Leadership, Creativity, Conflict Management, etc.), where each stream represents a single course. In Dimension 2D, activities would involve pausing the 1D streams and engaging in problem- or challenge-centered activities outside the classroom, integrating the knowledge from the active 1D streams. Here, the series would correspond to the student's academic year within the course.

With the annual series consisting of multiple knowledge streams in Dimension 1D and the implementation of activities encompassing these knowledge streams in Dimension 2D, the interaction of these various series forms Dimension 3D. The idea behind this dimension is that activities carried out in 2D are practices that involve teams of students from different series, integrating various levels of maturity and knowledge. For example, a group might consist of first-year and fourth-year students working together to solve the same problem, each contributing their skills. This setup promotes exchanging knowledge and experience, encouraging leadership, creativity, and planning in various ways.

Finally, in the proposed structure, Dimension 4D connects the activities carried out to address a problem or challenge (with mixed-year student groups in Dimension 3D) to a real-world issue originating from society, either presented by the community or identified by the course itself. These activities are typically framed within the concept of University Extension programs [5].

To understand the effectiveness of our proposal, we proposed a synthesis of this curriculum in a framework applied in an AIC discipline, conducting a descriptive case study over one semester with fourth-year Automation Engineering students at the University. In this framework, we proposed a pilot challenge called Student Xperience, encompassing the model's 1D, 2D, and 4D dimensions described in the previous section. The 3D dimension was not included in this study, as it was an initial study, and we opted to limit it to a single group of students (enrolled in AIC IV), allowing for better initial management of the pauses in the 1D knowledge streams to carry out the 2D activities. Finally, to characterize this study as a 4D activity, we focused on the challenge of irrigation problems in rice fields presented by a startup in the agribusiness automation sector (Green Next).

Describing the study, based on the semester timeline in which it was conducted, the 2D activity was divided into two times:

- **Time 1** – During this time, classes related to the 1D knowledge streams were paused for one week (the second week of the semester) to allow the company involved in the challenge to be introduced. This time included explaining its field of operation, business rules, projects, clients, etc. During this week, students also received mentorship to engage in discussions with the company's clients to understand their problems and generate ideas for potential developments. To foster student creativity, workshops on Design Thinking and Pitch creation were conducted, culminating in the formation of groups and the organization of initial tasks by the end of the time.
- **Time 2** – Repeating the strategy of Time 1, classes related to the 1D knowledge streams were again paused for two weeks (during the last month of the semester). During this period, students worked on developing their proposals, applying the knowledge gained in Time 1 to generate a solution for one of the client's problems. Among the practices carried out, they used Design Thinking to detail the problem and visualize possible solutions (Fig. 2) and detailed their final solution proposal (Fig. 3) in a technical report presented at the end of the challenge in a Pitch format.

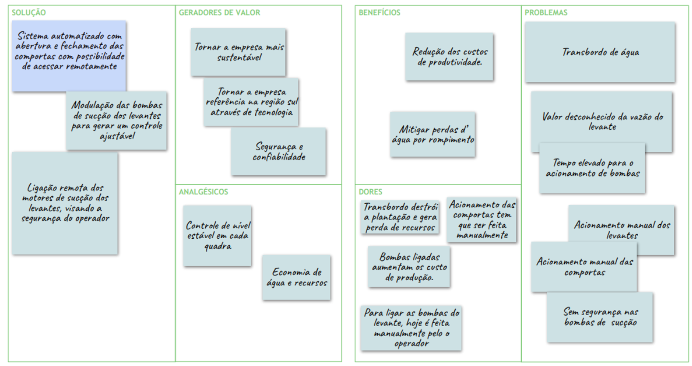

Fig. 2. Example of Design Thinking for problem detailing and possible solutions

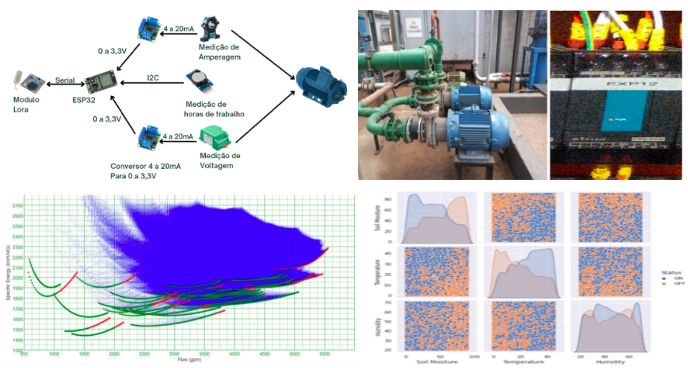

Fig. 3. Examples of final solutions presented by the students

Thirty students, divided into seven groups, participated in the experiment. Besides presenting their technical reports, they also shared their opinions on the experience at the end of the challenge (one response per group). These accounts were essential for analyzing the effectiveness of the practice and will be presented in the next section.

IV. Results and Discussions

An opinion survey was conducted with the students participating in the pilot experiment to validate the proposed framework. The responses were grouped using the Discourse of the Collective Subject (DCS) method, such as proposed by [20]. The DCS method allows researchers to understand and describe descriptive opinions and representations, enabling the delineation of behavior profiles. This method organizes and tabulates data obtained through testimonials, presenting itself as a qualitative verbal analysis option, resulting in synthesis discourses written in the first person singular, representing the thoughts of a collective.

The process consists of selecting, from each response, the **Key Expressions**, which are the most significant excerpts. Then, the **Central Ideas** are identified, synthesizing the discursive content manifested in the Key Expressions. The excerpts from the testimonials are then organized into synthesis discourses based on the Central Ideas. The following question was asked to gather the students' opinions: "**Based on the pilot study conducted, how do you evaluate the experience in terms of your expectations for innovations in the educational practices of the course?**" The resulting DCS from the responses is presented and discussed below:

"*The immersion in the real world of engineering application brought real problems for solving in the class. I believe it was a good way to learn the content studied throughout the course in practice, serving as an excellent alternative to the traditional approach of courses. The formation of groups was very relevant, as it encouraged socialization and teamwork, bringing dynamics and exchange of experiences, as well as cooperative work and networking, such as the interaction with the personnel from the partner company involved in the experiment. The experience of working with practical solutions for real challenges, presented by the company and the university, helped us students understand what is demanded by the market. It awakened not only our hard skills but also our soft skills, now seen as a master key for entering the job market, enabling us to give back to society what the university invested in our knowledge.*".

Analyzing the DCS that reflects students' responses, we sought to identify in their accounts the benefits of the proposed framework, guided by the objectives outlined in the introduction of this work regarding the challenges of a new current student-centered teaching model and its environment.

Regarding the factor where we aim to encourage **group work**, we identified in the passage "*The formation of groups was very relevant, as it encouraged socialization and teamwork, bringing dynamics and exchange of experiences, as well as cooperative work and networking*" an achieved objective. It is worth noting that the achievement of the proposal regarding student interaction is a significant factor in exchanging experiences and networking within the environment where the experiment was conducted.

Concerning the encouragement of **critical and autonomous thinking**, the passages "*The immersion in the real world of engineering application brought real problems for the class to solve*" and "*It awakened not only our hard skills but also our soft skills, which are now seen as a master key for entering the job market*" indicate that the framework met its goal as the students' accounts point out the need for problem-solving (motivating critical thinking), as well as the importance of developing their soft skills in practice.

As for the practices that promote **engagement with society and the productive sector**, the passages "*such as the interaction with the personnel from the partner company involved in the experiment*" and "*real challenges, presented by the company and the university, helped us students understand what is demanded by the market*" highlight the achievement of the goal. Note the importance of an activity that promotes the university's involvement with companies in the job market as valued in the students' accounts.

Finally, with the following passages "*I believe it was a good way to learn the content studied throughout the course in practice, serving as an excellent alternative to the traditional approach of courses*," "*The experience of working with practical solutions*" and "*enabling us to give back to society what was invested in our knowledge by the university*," we can conclude that the objective of **bridging academic theory with practical experience in society** was also achieved. At this point, it is worth noting the analysis that, in addition to the common sense of the benefits of innovatively providing the connection between theory and practice, students also identified the possibility brought by the experiment to give back to the society that invests in their knowledge development process.

V. Conclusions

In this paper, we present an innovative practice that offers a framework for integrating real-world engineering problems into the curriculum of an Automation Engineering course, with a focus on interdisciplinary aspects. This framework addresses institutional constraints and promotes interdisciplinary learning, offering a promising approach to engineering education.

The framework CV 4D considers a curriculum with four dimensions: (i) Dimension 1 is the disciplines; (ii) Dimension 2 is an interdisciplinary environment based on project-based learning; (iii) Dimension 3 integrates students from all course periods in the same problem and (iv) Dimension 4 establishes connections with society and industrial sector.

This framework is not just a concept, but a tangible solution. It is instantiated in a discipline aiming to create a Dimension 2 environment. By working with interdisciplinary aspects using project-based learning, it approaches soft skills in an entrepreneurial context using design thinking, thereby offering a host of benefits.

The results obtained in this work give pieces of evidence for scaling this framework at a curriculum level. The main findings are about the necessary resources to include all students in the 4D CV. The primary resources are projects in a quantity that can include all students. In this sense, it is necessary to strengthen an innovation ecosystem in the institution with sufficient projects, especially those in the industrial sector. Also, it demands some normative changes in the institution in a way that other curricular components, such as projects, can be included in the course curriculum.

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