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Research, Development and Innovation: An Extracurricular Club Case Study

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ABSTRACT Several approaches have demonstrated the effectiveness of project-based learning in the acquisition of students' academic outcomes and development of practical professional skills. In addition to academic engineering outcomes, professional skills such as teamwork, leadership, decision-making, entrepreneurship, intellectual property, and social commitment are considered crucial in this line of work. Taking the project-based learning technique and research development and innovation approaches as a starting point, a novel methodology is proposed, introducing students through extracurricular activities to a multidisciplinary methodology. The main objective is to facilitate the acquisition of professional skills that are useful in the professional life of every student, while high-quality engineering prototypes are produced. Multidisciplinary teams, including not only science, technology, engineering and mathematics majors, business management, and accounting majors, are also considered to generate significant learning with a strong connection to the environment. Students can apply theoretical and technical knowledge to the development of engineering projects while also acquiring professional skills. The effectiveness of the proposed methodology is demonstrated through academic results and a survey.

INDEX TERMS Multidisciplinary design, project based learning, prototyping, STEM, technology applications.

I. INTRODUCTION

Current society requires engineers with the skills to cope with modern, multifaceted challenges. In the context of science, technology, engineering, and mathematics (STEM) majors, interconnections between different areas can be difficult to foment [1]. In contrast, the application of technical and non-technical outcomes is required in professional practice [2], [3]. Moreover, the development of professional skills such as empathy, communication, teamwork, leadership, and decision-making is required [4]–[6]. Engineering projects require entrepreneurship, intellectual property, social commitment, [7]–[9], etc., which are often more relevant than technological content.

Multidisciplinary approaches should be applied during the university period to encourage the participation of students from diverse majors whose abilities can complement each other. This would make it important to present the majors' curriculum in such a way that students have the opportunity to apply their acquired knowledge to real problems [10]. Moreover, some practices have shown that engineering students are motivated to learn complex concepts when they can solve real-life problems through projects and teamwork [11], [12], such as active learning [13], [14].

Certain approaches to generating significant learning have also been applied. An appropriate example is project-based learning (PBL) [15], which has been implemented even in technical colleges [16]. PBL has demonstrated its effectiveness in STEM fields [17]–[19], including open-source hardware platforms [20], power electronics, DC/DC and DC/AC power converter subject matter [21], and electronic instrumentation for the development of biomedical instruments [22]. Classical PBL was applied without additional elements to improve the learning process.

Other approaches that may enhance the results of classical PBL have also been presented [23], [24]. In [25], an approach was applied to high school students, where PBL was used to engage students to think critically about the problems in their communities, following Freire's methodology. In [26], a hybrid methodology was presented, with the integration

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of academic and market-driven approaches. An elective course with a multidisciplinary project [27] was submitted to an intelligent environmental challenge. Regarding STEM, improved PBL has been used, for example, [28], where the authors proposed a role-playing game to encourage teamwork and self-management skills acquisition. In [29] an active learning PBL approach was applied to develop professional skills and engineering knowledge. In [30], an aquaponic prototype was presented to teach computational intelligence.

Although the available literature presents some results on how students' learning outcomes are improved, particularly for STEM areas, there are other ways of enhancing students' learning. Several countries have highlighted the importance of research, development, and innovation (RDI) in economic development; therefore, it would be convenient to include skills related to RDI in STEM majors [31], [32]. The interaction of students with their environment could enhance their understanding of the problems in their communities, propose technological solutions, and significantly increase learning [25]. Hence, RDI and contact with the environment could increase the impact of PBL on the acquisition of professional skills and academic engineering outcomes.

This paper describes an extracurricular methodology initiated in 2016. It focuses on students of STEM majors, RDI, PBL, and contact with the environment to provide technological solutions to real problems. The strategy was applied to a group of students, conforming to an extracurricular club on Centro Universitario de los Valles (CUValles), a campus on the outskirts of Guadalajara, the capital of Jalisco State, México. The students came from different majors and levels. The aim of the proposed methodology is to solve engineering problems from a multidisciplinary perspective by harnessing the different abilities of each team member. To increase the quality of developed products, RDI is considered in every project to provide direct applicability, feasibility of technology transference, and intellectual property protection, where significant learning is promoted. In this way, relevant projects can be obtained with direct application in the environment to solve real problems while involving the development of abilities that are not considered in the curriculum of the majors in CUValles. Moreover, the methodology promotes the acquisition of professional skills such as teamwork, leadership, decision-making, entrepreneurship, intellectual property, and social commitment, which are useful in the professional life of every student. The proposed methodology has been tested in the development of several projects; its effectiveness has been demonstrated through academic products and the results of a survey focused on determining students' perceptions of their performance.

II. PROJECTS DEVELOPMENT METHODOLOGY

This section outlines the proposed methodology, including the academic context of the campus.

A. CAMPUS CONTEXT

The University of Guadalajara has six campuses in the metropolitan area and nine regional campuses in smaller cities. Every campus meets the specific requirements of its region. The proposed methodology was applied at CUValles, located in the Valles region of Jalisco, México, approximately 80 km from Guadalajara City. The campus offers undergraduate degrees in Management, Engineering, Health, Humanities, and Social Studies. Although students have common spaces on campus, they do not share courses with different majors. It is uncommon for engineering students to learn about management and social issues as part of their curriculum.

Young people from 18 municipalities study on campus. Most of these are small rural towns and villages, with few steady employment opportunities. They experience medium to high rates of emigration, mainly to Guadalajara and the United States. Currently, the main sources of income stem from the agricultural sector, specifically corn and sugar cane cultivation, and the increasing production of berries. There is a demand for highly qualified engineers to develop the technology required by local industries and agribusiness. Professionals need to be well versed in technology transfer, intellectual property administration, entrepreneurship, social and ecological commitment, and so on.

Most students invest a significant amount of time and money in transportation because of the distance between the university and the nearest town. Additionally, students' classes on campus are scheduled only two or three days a week, with additional material and tasks on a virtual learning platform.

B. PROPOSED METHODOLOGY

The club is composed of undergraduate and postgraduate students organized in multidisciplinary teams to manage different projects. The majority of mechatronics, electronics and computing, information technologies, electronic instrumentation and nanosensors, biological systems, management and accounting, as well as a master's in mechatronics, are included. The club has its own infrastructure, with a designated area on the campus, computers, and laboratory equipment.

Considering the advantages of the PBL technique [33] and in order to fully develop every project, the students followed our proposed methodology, described in the next six steps (Figure 1). Although the final product is an engineering prototype, groups from different majors enable a multidisciplinary analysis. Multidisciplinary teams add value to the project; in addition to engineering, different areas are required, such as management and accounting.

1) PROBLEM DEFINITION

To maximize significant learning and the acquisition of new skills, three areas are considered when defining a regional problem: the environment, industrial development, and campus development, that is, prototypes for the benefit of the campus.

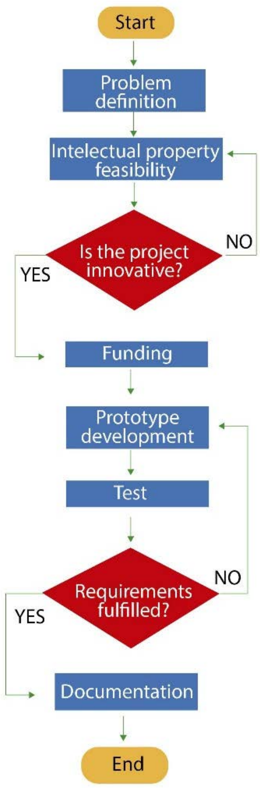

FIGURE 1. **Proposed project methodology flowchart.**

2) INTELLECTUAL PROPERTY FEASIBILITY

The feasibility of intellectual property was analyzed for each project. The goal is to identify similar or identical projects, patents or products. The results were analyzed and compared with those of the expected prototype. If there are enough differences with regard to the available technology, the project's funding is calculated, and an application for intellectual property is prepared. Furthermore, technological monitoring is considered part of the feasibility of intellectual property, and students must regularly conduct searches during the project to validate the innovation. In fact, these types of protocols are not yet evident in the existing literature as a stage of prototype development with a combined approach between PBL and RDI. At this stage, RDI has special relevance because the problems always have to be solved by considering technological innovations in the solutions.

3) FUNDING

In traditional learning, students only attend to the specifications of their teachers; they rarely have to conduct deep research about the problem to solve, much less make reports or prepare applications, as has been explained, this step is uncommon in the prototype development process. In the proposed methodology, an application is submitted, requesting a research and development or innovation grant. Certain financial sources have been considered, including Universidad de Guadalajara, the State Council of Science and Technology of Jalisco, Mexico, the Strengthening Educational Quality Program, and the Program for Professional Teacher Development, Mexico. The students learn to fill-in applications, write research protocols, and make reports in accordance with the characteristics stipulated by the founding sources. Writing protocols and reporting students will increase their critical thinking by presenting solutions directly to organizations.

It is important to highlight the role of students at the funding stage in coordination with professors. The applications are submitted to government institutions, which only provide economic support to projects with well-being for local communities, with an emphasis on social commitment. At this stage, the direct connection between the prototype and real problem is reinforced. Furthermore, the RDI is a guide for all participants to maximize the benefits of every prototype (i.e., patents, publications, etc.), which is a very important issue for institutions that provide funding. This stage is innovative in terms of the proposed methodology.

4) PROTOTYPE DEVELOPMENT

Prototype development was the main activity of every project in the club. Each team works at different stages of the prototype, which can include mechanical, electronic, embedded systems, and software. The four stages are designed and executed in the laboratories of the campus and are integrated into a single prototype that meets the final user requirements. The four stages can be carried out simultaneously by four students or four groups of students, who must have effective and efficient communication and teamwork skills. It is desirable to have multidisciplinary teams for each project to promote knowledge transfer between students.

5) TEST

Several tests were applied to each prototype in such a way that the system was subject to real operational and environmental conditions. The students became aware of the drawbacks and errors in the designs and had the opportunity to improve the prototype. Then, the students can practice identifying errors and improve the design and testing prototypes.

6) PROJECT DOCUMENTATION

The last stage entails documentation, which includes the generation of technical reports, test logs, photo books, business plans, financial reports, and operation manuals. This stage is a continuous process of collecting information and data while prototypes are being developed. In general, this documentation is more demanding than conventional reports as they are prepared for external entities that fund the project. Moreover, the students were required to elaborate a final presentation, where they showed the results. It can be made in a classroom or in a public forum, for example, a prototype contest.

As an element of documentation, the business plan presents business opportunities to the students, which is becoming a very important professional skill [7]. In this step, engineering, management, and accounting students have the opportunity to work together and acquire knowledge from various fields. As a matter of fact, business plans are the first step for an entrepreneurial venture. The students are able to continue the development to obtain a commercial product where the CUValles offer opportunities and advice, even though this is out of the scope of every project.

Again, RDI is an important component in the documentation, and students must demonstrate the proposed innovations, where the abilities acquired must be shown even in the written reports. Therefore, the documentation stage is an innovative element of the proposed methodology.

C. AUTOGESTIVE LEARNING

Figure 2 shows the activities that the students must perform in the process. First, multidisciplinary teams must be organized with at least one engineering student. The stated problem must be analyzed to propose a feasible solution, considering several issues, such as technical, economic, environmental, sustainability, context, and social commitment. The professors reviewed the recommended solution and made suggestions until all requirements were met. The team then began with theoretical design and intellectual property feasibility. Funding applications were written and submitted. Students develop the prototype according to their design, and several tests were performed to modify the design and prototype, if necessary, until the requirements are met. Finally, the documentation were prepared, with the conditions demanded by the funding institution, including technical reports, business plans, and test logs, as well as the final presentation.

These activities are included to significantly increase learning and critical thinking. The student must prove that the design meets the requirements by implementing the tests and organizing the information in the reports and final presentation. Figure 3 presents the connection between the procedures in Figures 1 and 2, as well as some examples of the outcomes achieved. Note that for every outcome, the approaches involved in the acquisition are included.

III. LEARNING ASSESMENT

The developed projects were used to demonstrate the effectiveness of the proposed methodology. To verify the acquisition of learning outcomes, two tools were applied to assess the reasoning process: a) a student evaluation rubric and b) a project evaluation rubric [34]. Moreover, techniques to supervise the projects and a survey were introduced.

A. STUDENT EVALUATION RUBRIC

A rubric for performance indicators of different students' learning outcomes was designed based on the standard criteria of international accreditation associations. The *Student Evaluation Rubric* includes results related to project planning, development, and documentation and was implemented to evaluate the individual performance of each team member. The Accreditation Board for Engineering and Technology (ABET) considers four levels: beginning, developing, proficient and exemplary [35]. A brief template of the rubric is presented in Table 1. The instructor assigned to the project applied to the rubric at the end of the project. The complete performance descriptors can be found in the following link: https://docs.google.com/spreadsheets/d/1usCVTIH25v49GSM1GJbsczx9w9V3PKciuaKmBI7_QFg/edit?usp=sharing

TABLE 1. Template for students' evaluation rubric.

Student:				
Outcome	Level			
	B	D	P	E
Design a project plan				
Express a real problem specs in a feasible prototype				
Use theoretical models to obtain specific performance in a prototype				
Establish fitness criteria to evaluate solutions				
Build a prototype with standard regulations				
Analyze a prototype performance				
Design tests in a prototype				
Analyze constraints and formulate a problem				
Generate alternative solutions				
Justify a solution proposed for a problem				
Provide data to report results				
Organize content in a report				
Collect proper data from the prototype				
Make an oral presentation				
Identify the global, economic, environmental and social context of a prototype				
Apply techniques, skills and tools to develop a prototype				

B=Beginning, D=Developing, P= Proficient, E= Exemplary

B. PROJECT EVALUATION RUBRIC

Team performance was also evaluated. Again, the standard criteria of international accreditation associations were taken into account [35]. The proposed template for the project evaluation rubric is presented in Table 2. The four levels in Table 1 have been reused here. Again, complete performance descriptors can be found in the links included above. The student evaluation rubric was applied in the final evaluation with external reviewers in a prototype contest.

C. PROJECT MONITORING

Instructors and students participated voluntarily and without payment. The main components of monitoring are described as follows:

Team oral presentations. Once a month, each team made an oral presentation to the instructor and other teams who gave them direct feedback. This activity was included to verify project progress and promote oral communication skills.

Partial reports. Once a month, every team delivered a partial report to the instructor, where project progress was included. In this case, the students developed written communication skills, synthesis, and teamwork.

Chronogram supervision. In the planning stage, students used the Gantt chart to define the time required for each activity. The instructor monitors compliance with scheduled activities. Students executed the activities in accordance with the Gantt chart or justified changes in the timeline to develop time management skills.

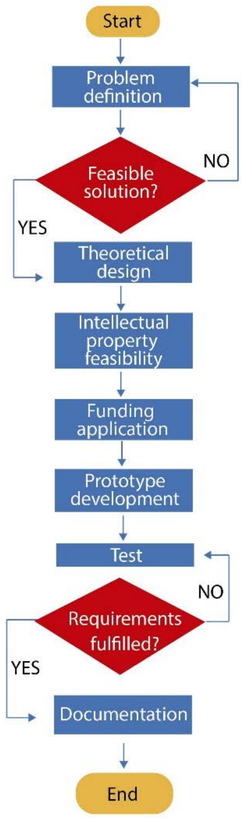

FIGURE 2. Students' activities in the proposed methodology.

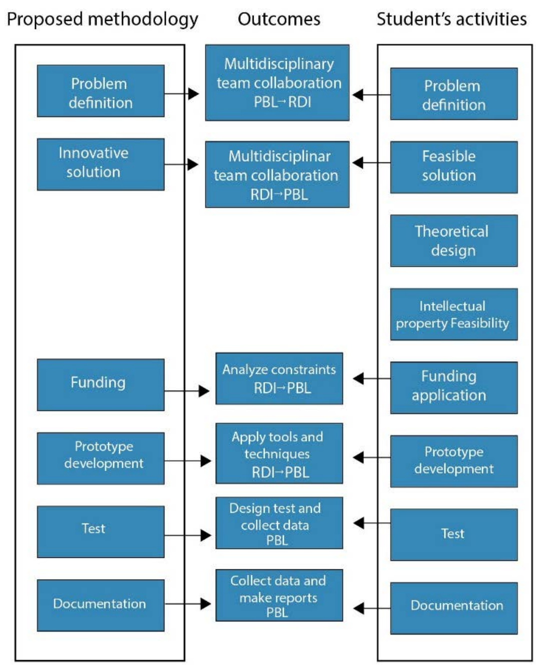

FIGURE 3. Relation between the students' activities and the proposed methodology.

Weekly meetings. Every team had a weekly meeting with the instructor, and the project progress was reviewed.

Partial demonstrations. Students showed the performance of some parts of the prototype that could be presented in the team's oral presentations or weekly meetings.

TABLE 2. Template for team's evaluation rubric.

Project:				
Outcome	Level			
	B	D	P	E
Design a project plan				
Express a real problem specs in a feasible prototype				
Use theoretical models to obtain specific performance in a prototype				
Build a prototype with standard regulations				
Analyze a prototype performance				
Apply tests in a prototype				
Justify a solution proposed for a problem				
Identify technical advantages of a prototype				
Identify technology transfer opportunities of a prototype				
Organize content in a report				
Demonstrate proper use of language				
Identify the global, economic, environmental and social context of a prototype				
Identify proper techniques, skills and tools to build a prototype				
Apply techniques, skills and tools to develop a prototype				

B=Beginning, D=Developing, P= Proficient, E= Exemplary

Prototype contest. This was the final activity. Teams presented prototypes to the university's academic community and external reviewers, who evaluated the learning outcomes acquired by the students using the *Project Evaluation Rubric*, as shown in Table 2. The aim of this activity was to prove every prototype and increase students' commitment to the project and its quality.

D. SURVEY

To measure the relationship between students' time investment and experience in the club, as well as the knowledge and professional skills acquired, a survey was designed, taking into account the methodology proposed in Section II. The survey comprised of three sections. The first section required the students to write a 32-line composition based on their own experience and opinion, where skills such as teamwork, leadership, time management, planning and organization, self-confidence, assertive communication, entrepreneurship, decision–making, and adaptation to changes are included. The second section asked students about their participation in each stage of the working process. The final section measured their self-perception of the changes in knowledge obtained since students first joined the club. A complete survey can be found on the link provided above.

The survey was conducted for the first time in 2019 as an invitation to every active and former club member. More than 60% of students answered the survey as a representative sample using simple random sampling. Currently, it is possible to present data derived from the first survey application.

IV. RESULTS

The proposed methodology, including the tools to evaluate and follow up on the projects, was proven for four years.

A. STUDENTS' PROFILE

Students' profiles are described in this section. In the four years reported in this paper, 20 students were in the club for one year, 12 for one semester, nine for three semesters, five for two years, four for five semesters, and the same amount for the maximum time of three years. The maximum frequency was one year, corresponding to the average time required to finish a prototype using the proposed methodology. The length of permanency was variable; it depended on the students' curricular activities, completion of their majors, or personal motivation. Seventy percent of the students participated in the club in the last third of their major.

A multidisciplinary composition is preferred for teams. Of the 54 students, 45 were registered in engineering majors, divided as follows: 21 electronic instrumentation and nanosensors, 18 mechatronics, 4 electronics and computing, and 2 biological systems. Four students from masters in mechatronics participated. In the case of administrative areas 3 students of management and two accounting students joined.

Furthermore, 16 students signed up for one project only, 21 students joined two different projects, ten students engaged in three projects, and four and three students were enrolled in four and five projects, respectively. To date, the maximum number of projects is five. Only 30% stayed in the club for this project.

As stated before, the students participated in the club as an extracurricular activity; hence, motivation is important, since the development of the projects requires time and effort. Some schemes to complete the entire major, such as community services and professional practices, were considered. Some students received grants to develop projects. Moreover, the students have access to the installations, equipment, materials, and advisory of the club, not only for project development, but they can also use the club's resources for other personal or institutional projects. Again, they pointed out that the students were part of the club without any additional benefits. The students have to schedule a few per week for the different activities in the projects, for example, in their free hours, or to assist one or two additional days. There are other activities that can be conducted at home, such as project documentation.

B. ACQUIRED OUTCOMES

Between 2015 and 2018, 54 students participated actively in the club, including 2 exchange students from Ecuador. 25 projects have been developed. According to the rubrics in Tables 1 and 2, the students showed proficient or exemplary levels in all outcomes.

Regarding individual evaluation, some of the assessed outcomes are part of the courses in engineering majors. Seven of the 16 outcomes in the students' evaluation rubric were not directly considered in any curricular course. Consequently, participation in the club promotes the acquisition of professional skills, which is different from that obtained in curricular courses. Considering the teams' evaluation rubric, five of the 14 outcomes are different from those presented in the students' evaluation rubric, where only two are considered part of curricular courses. Compared with the individual evaluation rubrics, three additional outcomes were included.

Thus, students' training alongside a robust connection with society is stronger when they work in the club. The inclusion of intellectual property is one of the main advantages of the proposed methodology. In the 25 projects, the teams obtained proficiency or exemplary grades.

To demonstrate the effectiveness of the methodology for obtaining products, some academic results were highlighted:

- 54 students from different majors from the CUValles voluntarily participated, as well as 2 students from Ecuador. A multidisciplinary team developed each project. 96.60% were registered in some of the undergraduate majors of the campus and 3.40% in a master's program.
- Eight industrial property registers, three patents, three utility models, and two industrial designs are obtained from the Mexican Institute of Industrial Property. Moreover, 11 applications in the same institution are under review, as is one international patent application.
- Six students participated in international academic exchange programs. Three received scholarships from the Emerging Leaders in the Americas Program for a four-month stay at Olds College, Alberta, Canada.
- Five papers were published in international journals indexed in the Web of Science, with four submitted for evaluation.
- Three papers have been presented at international conferences.
- A book chapter has been published.
- Five theses for STEM majors have been concluded.
- Eight theses for STEM majors are in progress.
- A total of US $116,865.50 in funding was obtained for acquiring specialized equipment, laboratory materials, building structures and mechanisms, and student grants, including programs of Universidad de Guadalajara, the State Council of Science and Technology of Jalisco, México, the Strengthening Educational Quality Program, and the Program for Professional Teacher Development, México.

A summary of the project results can be found in the link provided above.

C. SURVEY

The survey was composed of 50 questions related to professional skills, which can be found in the link previously provided. The survey results showed that the students perceived real improvements in their knowledge related to the different stages of the work process. Students' self-perceptions are presented in Table 3. Every student had the opportunity to participate in the six stages of the project process.

TABLE 3. Student self-perception of knowledge acquired in the stages of the projects process.

Stage	N		Ba		E		A		Total	
	B	T	B	T	B	T	B	T	B	T
Problem definition	3	0	**21**	1	8	**21**	0	**10**	32	32
Intellectual property feasibility	**15**	0	**14**	13	2	**16**	1	3	32	32
Funding	**19**	1	**8**	9	5	**20**	0	2	32	32
Prototype development	3	0	**15**	1	11	**15**	3	**16**	32	32
Test	3	1	**17**	0	8	**16**	4	**15**	32	32
Project documentation	4	0	**18**	3	6	**20**	4	9	32	32

N= Nonexistent; Ba= Basic; E= Enough; A= Advanced; B= Beginning; T= Today.

TABLE 4. Average level of involvement in each stage, rated: min 1 – max 5.

Stage	1	2	3	4	5	6
1 project	3.00	1.71	2.00	3.71	3.57	2.71
2 projects	4.22	3.00	2.56	4.67	4.67	4.33
3 projects	4.27	3.00	2.82	4.18	4.18	4.36
4 projects	4.25	2.75	3.00	4.75	4.50	4.75
5 projects	4.00	4.00	4.00	5.00	5.00	5.00

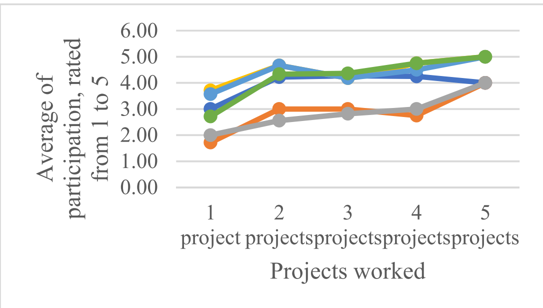

FIGURE 4. Increased in average involvement at each stage of the work process.

Table 3 shows that students perceived that before joining the club, their applicable business and engineering knowledge was limited. Few affirmed having either sufficient or advanced knowledge in the beginning. Most of the students declared that their knowledge had improved to "enough" or even "advanced" at the time of the survey. Table 4 and Figure 4 show the students' perceived level of involvement in the different stages depending on the number of projects worked. Each student, as a member of the club with the freedom to choose with whom they want to work, decides how much time to invest in the project in agreement with the instructor and deadlines.

Students were asked to rate their perceived level of involvement at each stage of the work process. Once the answers were correlated with the number of projects that each student had participated in at the time of the survey application and the averages for each stage of the work process were calculated, it was apparent that the level of involvement increased as the number of projects increased.

Regarding professional skills, the survey results showed high levels of initiative and commitment to quality in members' profiles. These skills are important to their academic and professional performance, and it is probable that they are part of the personal features that motivate students to participate in programs such as the Club.

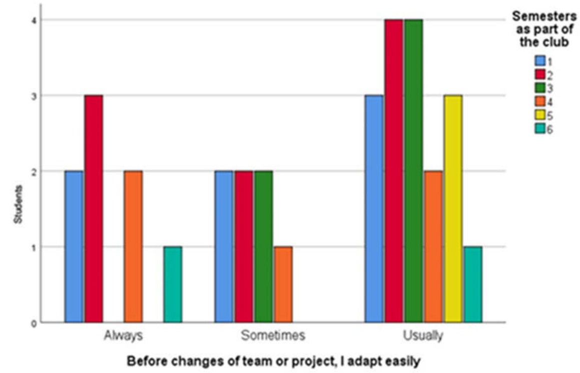

FIGURE 5. Survey results about changes and adaptation.

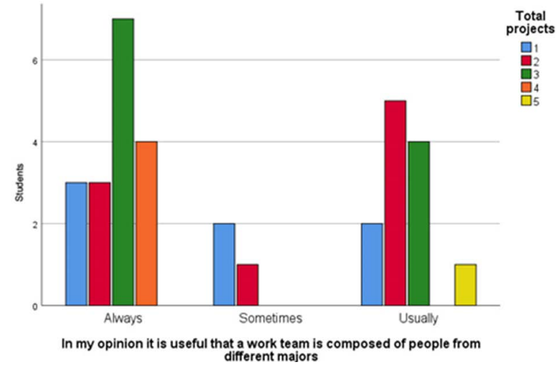

FIGURE 6. Survey results about multidisciplinary teams.

70% of the students affirmed to meet the deadlines of their assigned projects, despite having other non-related commitments; in addition, those who participated for four semesters or more in the Club, developed their own schedules to manage their time per task. These findings demonstrate the development of professional skills, such as planning, organization, accountability, and stress management.

Furthermore, the more time and effort students invested in the club, the more autonomy and assertiveness students perceived themselves, which reflects on acquired skills such as decision-making and adaptation to change, as shown in Figure 5.

Students who have been part of the Club for the longest affirm greater willingness to recognize and correct errors found in their own work and their partners in the team. They perceive that they have developed skills such as giving constructive criticism, practicing self-criticism, and assertive communication, features that stand out among those who assume leadership roles. In addition, the more projects students developed, the more conscious they were about the importance of a multidisciplinary team, as shown in Figure 6. Neither gender nor age were considered to have an impact on work.

In the case of leadership and motivation, students with longer periods of participation considered themselves more self-confident and had strong leadership and motivational skills, as shown in Figure 7.

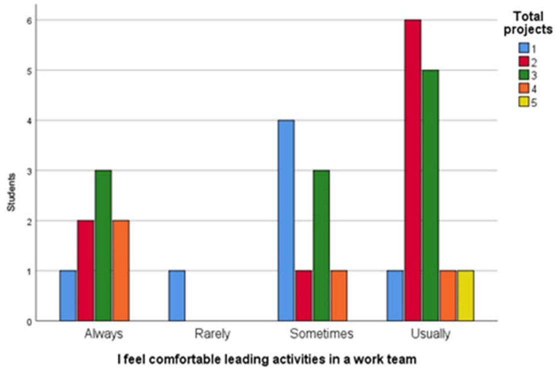

FIGURE 7. Survey results about leading.

D. SUGGESTIONS FOR IMPLEMMENTATION

To facilitate the implementation of the methodology, the following remarks must be included:

- The instructor's profile is relevant, and an engineering profile with professional experience and knowledge in project management is needed. Since some techniques can be applied to every project and team, this knowledge is shared with students.
- Because all projects are different, several project management techniques could be applied and modified during the project, considering, for example, contingency theory [36]–[38], to adapt the tasks according to the prototype needs, which is another additional ability provided by the proposed methodology.
- In addition to instructors with a technological profile, some advisers participated in the entire project development for other areas (e.g., intellectual property, business plans, social commitment, chemical, physics, etc.).
- To obtain better prototype results, integration between undergraduate and graduate students is preferred. In this way, there is a knowledge transfer between the different levels, and the scope of RDI can be increased.
- Although the main product of every project is an engineering prototype, there are other areas that must be considered, such as business plans. Therefore, it is necessary for multidisciplinary teams to address every issue in the methodology.
- Multidisciplinary teams enable the coverage of different aspects in the prototype; this is included in the problem definition.
- The problems considered are directly related to current challenges in the region, and as a consequence, the proposed solutions are relevant to the students and increase their social commitment.

V. CONCLUSION

This paper presents a methodology that combines PBL and RDI approaches, applied as an extracurricular initiative that includes innovative elements such as intellectual property, funding, and documentation with strict requirements, centered on real problems in the environment of students, to propose feasible solutions. This methodology was applied to multidisciplinary teams of students at a Mexican university. The academic results show the efficacy of the proposal since the assessments demonstrate the acquisition of technical and professional outcomes. Several products have been obtained, including educational prototypes, industrial prototypes, papers, industrial property applications, and theses. Furthermore, students expressed in a survey the improvement in solving complex environmental and user problems.

The obtained prototypes met the quality standards and environmental needs. As a result, students are able to acquire academic and technological skills as well as professional skills such as teamwork, leadership, decision-making, entrepreneurship, intellectual property administration, and social commitment. Meaningful learning is facilitated by a strong connection to the environment.

A comprehensive methodology was presented, including the different steps, characteristics of the proposed projects, rubrics for the assessment, and detailed survey. Finally, the proposed methodology can be implemented at other schools and universities worldwide.

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