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EDITED BY
Danijel Dankovic,
University of Niš, Serbia

REVIEWED BY
Peter Robin Childs,
Imperial College London, United Kingdom
Lucía Seguí,
Universitat Politècnica de València, Spain

*CORRESPONDENCE
Luis Neri
✉ neri@tec.mx

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# Acquisition of transversal competencies through a project-based learning model for computer systems engineering students

Julieta Noguez[1], Enedina Ortega Gutiérrez[2], Luis Neri[1]* and Julio E. Rubio[2]

[1]Engineering and Science School, Tecnologico de Monterrey, Mexico City, Mexico, [2]School of Humanities and Education, Tecnologico de Monterrey, Mexico City, Mexico

**Introduction:** This article presents an innovative educational practice to promote transversal competences in computer engineering university students, through Project Based Learning (PjBL), providing students with the benefit of experiential learning. Challenges of a social nature were chosen, which are related to demographic aging. Once the course information has been collected, the challenge was to identify whether the students have really acquired the cross-cutting competencies that they should have developed on the course.

**Methods:** After applying the model and pedagogical design of the Project-Based Learning (PjBL) methodology, and given the characteristics of the information sources used, a research design was carried out from a qualitative approach through the grounded theory method whose purpose is to induce substantive theory, related to learning, application, and emergence of transversal skills and the pedagogical strategy of the course.

**Results:** The cross-cutting competencies identified were collaboration for efficient teamwork, communication among team members, and support and communication with the teacher and were noted to be of great importance for finishing with a high-quality final project.

**Discussion:** Unlike other studies that are based on the evaluation of learning through grades, self-reported questionnaires, rubrics, tests, interviews, observation, self-reflection journals, etc., this research was conducted from a qualitative approach through the grounded theory method. According to the results obtained, it has been possible to identify the most relevant language elements for the studies and thus infer the acquisition of transversal competencies in university students of computer engineering, developed through the PjBL technique, providing students with the benefit of experiential learning.

KEYWORDS

**project based learning, transversal competences, higher education, innovation education, social character projects**

## Introduction

In recent decades, there has been a growing interest in promoting active student learning through methodologies based on experience and inquiry, in which students build their own knowledge and develop disciplinary and transverse competences by proposing solutions to real-world problems and challenges. These methodologies are focused on the students and not on the teacher, who now becomes a facilitator who supports the co-learning of the students while they develop their solutions. In this way, students advance at their own pace, usually working in teams, giving different solutions to the challenges posed. Project-Based Learning (PjBL) (Kokotsaki et al., 2016), Problem-Based Learning (Du and Kolmos, 2006), Challenge-Based Learning (CBL) (Leijon et al., 2021), and experiential learning (Kolb, 2014), are examples of these inquiry-based methodologies.

Project-based learning (PjBL) or Project Oriented Learning (POL) has been implemented among inquiry-based methodologies. This didactic technique represents an active student-centered instruction model in which authentic real-life projects are presented to students with the aim to promote student motivation and engagement in finding an appropriate solution for the project. During the project, students can face diverse problematic situations that need to be solved to develop the required final product (Kokotsaki et al., 2016; Noguez and Espinosa, 2004; Noguez and Sucar, 2006). PjBL follows a precise methodology and has been used in various contexts, disciplines, and academic levels (Du and Kolmos, 2006; Johnson and Ulseth, 2014; Soparat et al., 2015; Kokotsaki et al., 2016; Brassler and Dettmers, 2017; Bakar et al., 2019; Fajra et al., 2020; Owens and Hite, 2020; Granado-Alcón et al., 2020). Through the project development students are expected to develop transverse or soft skills in addition to disciplinary competencies (Baird, 2019; Granado-Alcón et al., 2020).

This article presents an innovative educational practice to promote transversal skills in computer engineering university students, through PjBL, providing students with the benefit of experiential learning. The selected course is Analysis and Design of Software Systems, from the sixth semester of the Computer Technology Engineering major, and focuses on the knowledge and application of methodologies, techniques, and modeling tools for the development of object-oriented software. Additionally, this course promotes the development of transversal skills, such as the production of innovative and versatile solutions in changing environments that create value and positive impact. In this case, the problem is related to the elderly and the organizations that care for them, so that they use the available computer tools to monitor and give guidance to caretakers. The challenges of the course were aimed at the development and use of applications through the provision of technological solutions to social problems that promote healthy aging and/or prevent and mitigate frailty syndrome in the elderly.

Challenges of a social nature were chosen, which are related to demographic aging, because it is a continuous and growing process, with subregional and inter-country variations according to ECLAC data (Huenchuan, 2018; Kanasi et al., 2016). It offers an ideal setting for the teaching and learning of transversal skills for teachers and students of the Software Systems Analysis and Modeling course, by linking the course to the attention of the problems and needs posed by public and private institutions that offer various services to the elderly population through the development of technological applications. With this it is possible to sensitize students about social problems and acquire a commitment to the real needs of older adults and the organizations that serve them.

Moreover, it has been identified that the students who participated correspond to the characteristics of young people denominations such as "Hashtag Generation" (Feixa et al., 2016; Colombani and Sanderson, 2015). That is, from students who were born in the 90's and who were fully trained in the digital age. These features allow young people to face real world challenges through participation and awareness in the development of technological applications for real users.

The research questions raised in this work are:

- *Can the internal work contract documents of the teams and group processes prepared by the students be considered evidence of the application, acquisition and appropriation of the transversal competences envisaged for this course?*
- *What transversal competences are developed by the students in the course designed with the Project-Based Learning (PjBL) educational model through the development of the project (oriented to the thematic lines of healthy aging, prevention, and mitigation of frailty syndrome), emerging from the students' reflection documents: group processing, collaboration with the advisor professor, and final conclusions?*

The document is structured as follows: Section 2 includes the theoretical framework that supports the present research, Section 3 describes the related work to the topic of Project-based learning; Section 4 contains the description of the methodology; Section 5 includes the case study; Section 6 carries out the analysis of results and discussion, Section 7 presents the discussion, and, finally, Section 8 shows the conclusions and future work.

## 2 Theoretical framework

This section includes some relevant concepts related to the research work presented here.

### 2.1 Development of competencies in experiential learning

There are countless definitions of skills and abilities, finding that they are treated as synonyms. The term competence in the educational environment is linked to the capacity, ability, skill, or experience to do something specific or deal with a specific topic. In conceptual pedagogy, the concept of competence is used to analyze the development of thought (Pérez-Porto and Gardey, 2008). This concept is closely related to training and the way in which mental structures are modified to capture a clearer vision of reality.

At Tecnologico de Monterrey, a competence is a performance that is carried out to solve a specific situation according to certain criteria. In this action, knowledge, skills, attitudes, and values are consciously revealed in an interrelated and relevant manner

(CONECTA, 2024; Tec21, 2024; UWN, 2024). According to this, it is possible to identify if students have acquired the competences when they can:

- Consciously carry out an action in an intentional and pertinent manner that satisfactorily addresses or resolves a specific situation, in accordance with the expected quality criteria.
- Apply knowledge, skills, attitudes, and values to successfully solve or address a specific real-life problem, need, or task.

However, one of the most important challenges that teaching staff face is the competences assessment process. Competence-based assessment implies, among other things, that these must be demonstrated by the student through specific types of evidence. This requires the definition of adequate performance criteria that allow the teacher to assign the student a given level of competence. It should be noted that this type of evaluation does not exclude the common verification of the theoretical and conceptual mastery that necessarily supports the competence. In this sense, a comprehensive and integrated assessment of knowledge, skills, attitudes, and values in action is required (Villa and Poblete, 2007; Valverde et al., 2012; Keinänen et al., 2018; González-Salamanca et al., 2020).

## 2.2 The problems of the elderly and the organizations that care for them

According to data from CEPAL (Bárcena, 2018), demographic aging is an ongoing and established process, with sub regional variations and between countries. Globally, between 2015 and 2030, the population aged 60 and over will rise from 900 million to more than 1.4 billion people. This represents an increase of 64% in just 15 years, being the age group that grows the most. In the case of Latin America and the Caribbean, the aging process advances faster than in developed countries, particularly the subregion where Mexico is located (Huenchuan, 2018).

The National Employment Survey (INEGI, 2022) estimated almost 18 million older people residing in Mexico by 2022, representing 14% of the total population. Mexico City, where our study is conducted, has the highest rate of aging in the country. According to this report, the quality of life of older adults is determined by various factors such as health, sexuality and falling in love, the relationship with the environment, the management of technology, the use of free time, support networks, and life satisfaction (Boulton-Lewis, 2010; Gatto and Tak, 2008).

In particular, the approach of supporting older adults using technology has broad benefits, which include the following:

- Motivate learning, increase communication, avoid isolation and loneliness, and provide a factor that promotes and accompanies active aging.
- Offer technological resources to serve the elderly, their families, caregivers, and service providers both in the public sector and in civil society organizations.
- Provide accessibility and use of available information resources, as well as the development of applications that respond to the specific needs of the elderly.

## 2.3 Grounded theory

The Grounded theory methodological perspective (Charmaz, 2015, 2006; Barrios, 2015; Soneira, 2007) was selected in the present research based on two interests: (i) Identify the regularities and patterns in the acquisition and appropriation by students of transversal skills, and (ii) Understand the meaning in the context of the text and the actions from the perspective of the students of how and where the competences are acquired and their relevance in the different phases of the project.

Developed by Barney Glaser and Anselm Strauss (Glaser and Strauss, 2017), the Grounded Theory (GT) is a systematic methodology in the social sciences that emphasizes the generation of theory from data. This theory is distinct in its inductive nature, allowing theories to emerge from the data rather than testing pre-existing hypotheses. Over the years, the methodology has evolved, with significant contributions from Juliet Corbin with Strauss (Strauss and Corbin, 1997; Corbin and Strauss, 2014).

The Grounded Theory is rooted in the pragmatist and symbolic interactionist traditions, emphasizing the importance of understanding social processes and interactions. The methodology is characterized by its iterative process of data collection and analysis, which involves constant comparison, coding, and theoretical sampling (Glaser and Strauss, 2017; Glaser, 1978; Strauss and Corbin, 1997). The goal is to develop a substantive theory that is "grounded" in empirical data and information systematically collected and analyzed. The theory has been widely applied across various disciplines, including sociology, nursing, education, management, and psychology (Charmaz, 2006; Corbin and Strauss, 2014; Bryant and Charmaz, 2007). Its flexibility and inductive nature make it suitable for exploring complex social phenomena where little prior theory exists.

The main elements of the methodology of this theory are the following:

1. *Constant comparison*: This is the core analytical process in GT, where data are continuously compared to identify patterns and categories. Researchers compare incidents, concepts, and categories to refine their understanding of the emerging theory. It is emphasized that constant comparison allows researchers to move beyond descriptive accounts to develop abstract theoretical concepts.

*Coding*: Coding is the process of labeling and organizing data into categories. Glaser and Strauss initially proposed two types of coding: open coding (breaking down data into discrete parts) and selective coding (integrating categories to form a core theory) (Glaser and Strauss, 2017). Corbin and Strauss later introduced axial coding, which involves identifying relationships between categories (Corbin and Strauss, 2014). Axial coding helps to organize data into a coherent framework by linking categories to subcategories and contextual conditions.

2. *Theoretical sampling*: Unlike traditional sampling methods, theoretical sampling is driven by the emerging theory. Researchers collect data from sources that can help refine and validate the developing categories and concepts. It is argued that theoretical sampling ensures that the data collected are relevant to the emerging theory, enhancing its explanatory power.
3. *Theoretical saturation*: This occurs when no new categories or insights emerge from the data, indicating that the theory is well-developed and comprehensive. Saturation is a critical criterion for determining when to stop data collection.
4. *Memo writing*: Memos are written throughout the research process to document ideas, reflections, and theoretical insights. They serve as a bridge between data collection and theory development. Glaser highlighted the importance of memo writing in capturing the researcher's thought process and refining theoretical concepts (Glaser, 1978).

Summarizing, the grounded theory is therefore a substantive theory that can be developed from the study of a limited area of research and a specific population, and the merit of this theory lies in its ability to speak specifically of the populations from which it is derived and to which it should be applied (Birks and Mills, 2015; Thornberg and Dunne, 2019).

## 3 Related work

Project-based learning (PjBL), also known as project-oriented learning (POL), is an active, student-centered teaching model where students engage in a real-life project designed to motivate and involve them in finding solutions to complex issues (Lavado-Anguera et al., 2024; Zhang and Ma, 2023; Guo et al., 2020). This method fosters students' autonomy, investigative skills, goal setting, collaboration, communication, and reflection as they work on real-world tasks or large-scale projects (Noguez and Sucar, 2006; Noguez and Espinosa, 2004). Throughout the project, students encounter various challenges that they must solve to produce a final product in response to a driving question (Kokotsaki et al., 2016).

PjBL has been applied across different educational contexts, disciplines, and academic levels, ranging from primary schools to higher education (Du and Kolmos, 2006; Johnson and Ulseth, 2014; Soparat et al., 2015; Kokotsaki et al., 2016; Brassler and Dettmers, 2017; Bakar et al., 2019; Fajra et al., 2020; Owens and Hite, 2020; Granado-Alcón et al., 2020). A key feature of PjBL is its ability to promote both technical and transversal (soft) skills alongside discipline-specific knowledge. This approach helps students acquire essential competencies such as problem-solving, teamwork, leadership, and self-directed learning, which are increasingly valued in both academic and professional settings.

Several studies have explored the development of both technical and soft skills through PjBL. Noguez and colleagues (Noguez and Sucar, 2006; Noguez and Espinosa, 2004) reported significant improvements in the development of technical skills, such as information systems modeling and documentation, as well as soft skills, including problem-solving, teamwork, and self-directed learning, among software engineering students at Tecnologico de Monterrey in Mexico. Similarly, Du and Kolmos highlighted how PjBL in engineering courses at Aalborg University in Denmark helped students gain process competencies, such as teamwork and professional identity, by simulating real workplace environments (Du and Kolmos, 2006). Other studies, such as those by Soparat et al. (2015) and Rubinacci et al. (2017), have emphasized the development of key competencies like communication, critical thinking, and problem-solving through PjBL in various contexts, such as ICT integration in Thai education and robotics projects in primary and secondary schools, respectively.

PjBL also plays a significant role in enhancing language skills, as demonstrated by Tseng and Yeh (2019), who applied the methodology to improve Computer-Assisted Language Learning (CALL) competencies among English as a Foreign Language (EFL) teachers. Furthermore, Granado-Alcón et al. (2020) observed moderate to high development of both general and specific competencies, including teamwork, problem-solving, self-learning, and communication, among students engaged in PjBL projects. This method also fosters knowledge transfer, enabling students to make connections between different subjects and areas.

The importance of PjBL in fostering creativity and twenty-first century skills is also underscored by studies like those of Novalinda et al. (2020) and Fajra et al. (2020), who examined its impact on vocational high school students in Indonesia. Additionally, Nazaré de Freitas and Almendra proposed a conceptual map to categorize the soft skills developed through PjBL in design education, distinguishing between interpersonal and cognitive skills (Nazaré de Freitas and Almendra (2021).

Recent literature reviews have highlighted the positive outcomes of PjBL across various disciplines and educational levels, particularly in the development of real-world skills and academic achievements (Lavado-Anguera et al., 2024; Zhang and Ma, 2023; Guo et al., 2020). These reviews suggest that students who engage in PjBL not only develop thinking skills and twenty first-century competencies but also show improved attitudes and behaviors toward learning. However, many studies focus primarily on higher education and the design of PjBL courses, with less attention given to the assessment of transversal competencies acquired by students.

In summary, Project-based learning (PjBL) has proven to be an effective method for promoting both technical and soft skills in students across various disciplines and educational levels. The method emphasizes real-world problem-solving, collaboration, and self-directed learning, while also fostering key competencies like communication, critical thinking, and teamwork. Although much of the research on PjBL focuses on higher education and specific disciplinary skills, there is an emerging need for further investigation into the transversal skills students acquire through this approach.

## 4 Methodology

The methodology applied in this work was divided into three major phases: (a) design of the learning experience; (b) application

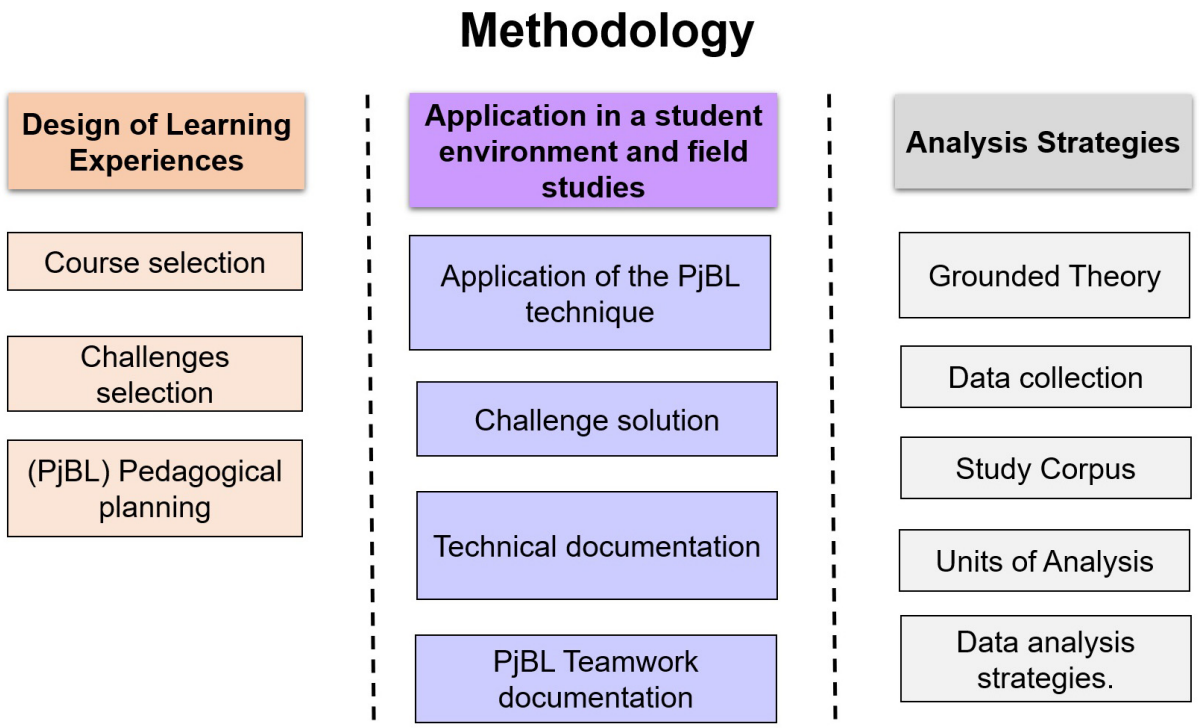



FIGURE 1
Methodology applied in this study.

in a student environment and field studies; and (c) Evaluation of transversal competences (Figure 1).

## 4.1 Design of the learning experience

Among the technical skills that a project can help to develop are the ability to identify and solve organizational problems, the application of tools to model the problem, the development of skills for the preparation of technical manuals and the integration of knowledge from various sources. disciplines. In a project under the PjBL technique, the student is expected to learn to solve unresolved problems, using relevant knowledge regardless of the discipline it comes from. The work is focused on exploring and working on a practical problem with an unknown solution. The projects must be designed in such a way that they cover at least one course and can involve several contents of the same discipline to the interaction of several of them. The project should also allow the search for open solutions in such a way that the student has the freedom to generate new knowledge.

In this study, Computer Technology Engineering students enrolled in the Analysis and Design of Software Systems course between January 2018 and June 2021 were considered. The student sample included 114 students, organized into 24 teams of between 4 and 5 participants each. Although during 2020 and 2021 the course was taught online because of the COVID19 pandemic, due to the nature of the course and the technological resources provided by the institution, satisfactory results were also achieved for these sections where no poor performance was perceived in solving the challenges posed, compared to the face-to-face sections. Next, the main characteristics of the course, the definition of the challenges, the organization of the students and the focus of the study are described.

### 4.1.1 Course selection

The selected course is in the 5th semester of the Computer Technology Engineering career, which is characterized by having a flexible and dynamic structure. In the periods prior to confinement due to the pandemic the course was taught face-to-face, combined with various technological resources and the use of different media and online platforms such as the Zoom platform, if students and/or clients/users of the system could not travel to the Campus facilities. During confinement due to the pandemic, the course was taught entirely online, through different technological tools such as the CANVAS educational platform, Zoom, and WhatsApp communication and interaction platforms. The following elements were also incorporated into the teaching-learning process: information technologies, software development platforms, CASE (Computer Aided Software Engineering) tools, educational software, and other tools that students discovered through self-learning, peer co-learning, knowledge, and skills coming from other subjects and from their field experience.

The objectives of the selected course are:

- Know and properly apply different models of the software development life cycle.
- Know and successfully apply different models for the analysis, design, and elaboration of systems.

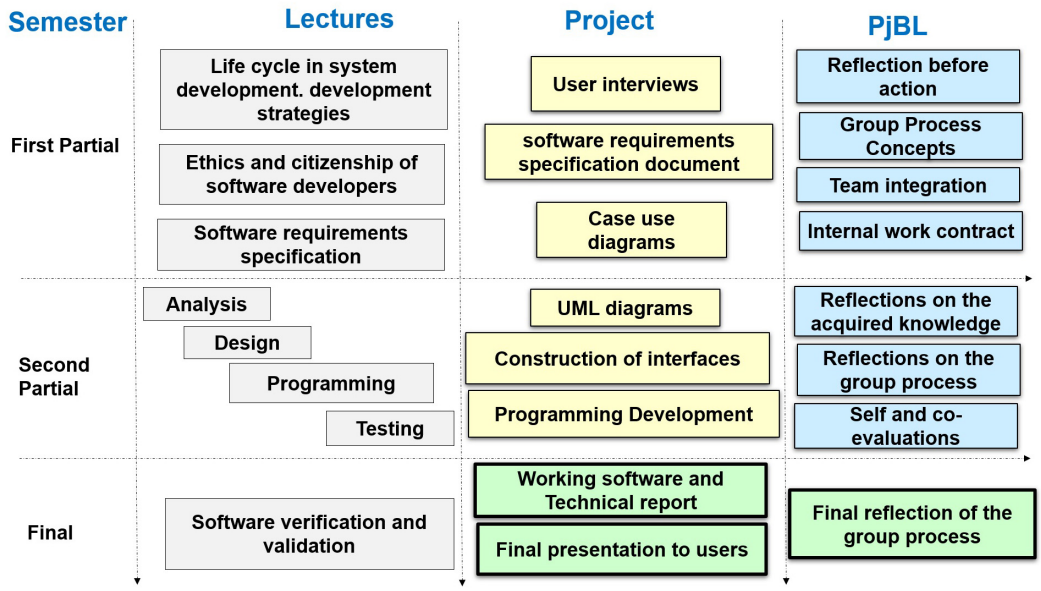



FIGURE 2
Model and strategic planning of the analysis and design of software systems course.

- Know and apply different software development environments, programming languages, and computational tools to solve a problem.
- Sensitization and awareness on the topic of healthy aging.

The transversal or soft skills that students must develop on the course are:

- Communication. Through the completion of written and digital documentation and oral presentations of the progress of projects in the IT area in a satisfactory manner.
- Ethical and citizen commitment. Through the implementation of projects aimed at transforming the environment and common wellbeing with ethical awareness and social responsibility.

Students were asked to form free-form teams of 4-5 people, preferably with compatible class schedules. Once the teams were formed, they were given classes on how the PjBL works, how to organize themselves in a Software Development Team (Pressman, 2010), and how to draw up an internal work contract.

### 4.1.2 Defining challenges for students

Course Challenges were defined that would allow students to know and apply the main methodologies, techniques, and modeling tools for software development, to develop high-quality software, easy to operate and update, and that meets the quality needs of social organizations. As previously mentioned, due to demographic changes, the elderly are a priority group to be addressed, especially if it is considered that every older person gradually presents functionality and health problems associated with aging. Therefore, students were asked to develop appropriate apps and online systems to provide support and services for elderly people, as explained later.

### 4.1.3 PjBL pedagogical planning

The pedagogical planning of the course, which incorporates the Project Based Learning technique (PjBL), is shown in Figure 2. It shows how the course contents are aligned with the project products and the elements of the PjBL technique.

The disciplinary evaluation and the quality of the projects were carried out successfully. However, the evaluation of the transversal competences or soft skills acquired by the students has had a greater degree of difficulty and generated controversy due to the diversity of opinions of the various evaluating professors. For this reason, in the present research it was decided to determine alternative or complementary methods in the evaluation of this last type of competence and the awareness acquired by carrying out social challenges.

## 4.2 Application in a student environment and field studies

For the application of PjBL in the students' environments it is necessary to know their status and progress both in the project and in their cognitive development and acquired skills. For the disciplinary and cognitive evaluation, students present their work products resulting from the project (technical documents, code, working software or artifacts, exams, learning activities, etc.).

On the other hand, students are required to elaborate documents that guarantee their collaborative work at different times during the project, as well as reflections during the course and at the end of it. Among them are:

1. *The internal employment contracts.* At the start of the project, students are required to form teams and are asked to prepare a document in which they establish their form of organization, the rules of operation of the team and

the roles and commitments they acquire to successfully develop the course project.
2. *Portfolio of reflections*. It contains the continuous reflections that the teams and their members experience as the development of the project progresses and that are finally integrated into the final document called the Group Process.
3. *Group process document*. At the end of the project, a group process analysis document is prepared, in which students must synthesize their experiences, achievements, and reflections during the project on individual and team portfolios.

## 4.3 Technical documentation

Since it was considered as a formal project delivery, it was very important to let the user perceive that they received the "final product" of all the development work. Teams were asked to generate technical documentation for each of the following sections:

- Requirement specification document (SRS-830 IEEE)
- UML Modeling
- Test Plan
- Programming Code
- User information
  - System user manual
  - Installation manual

## 4.4 PjBL teamwork documentation

These documents included the final reflections/conclusions of the team at the end of the course, and after concluding their projects. They contain final conclusions and describe how the members of the team worked during the project. To elaborate these documents, the students had to consider individual, and group reflections made through the different stages of the project.

- The initial expectations of the team
- Collaborative work within the team
- Individual Contributions to group work
- Aspects of participant's co-evaluation
- Conclusion
- Collaboration aspects with professor
- Group phase general conclusions

## 4.5 Evaluation of transversal competences or soft skills

Once this information has been collected, the challenge is to identify whether the students have really acquired the soft or transversal skills that they should have developed in the course.

After applying the model and pedagogical design of the Project-Based Learning (PjBL) methodology, and given the characteristics of the information sources used, a research design was carried out from a qualitative approach through the grounded theory method whose purpose is to induce substantive theory, related to learning, application, and emergence of transversal skills and the pedagogical strategy of the course. To this aim, the study was based on empirical data extracted using NVIVO software from the corpus of two types of documents produced by the students: i) the initial internal work contract, and ii) the final group process, where the students record their reflections, experiences, processes and learning during the project.

The activities carried out in this phase of the study are Study corpus, Units of Analysis, Phases of data collection, and Data analysis strategies.

# 5 Case study

The case study analysis strategies are described below.

## 5.1 Characteristics of the students

The sample of students used belong to "#generation" (Feixa et al., 2016), which includes people born in the 90's, and are fully educated in the digital era, whose arrival to youth in the 2010 decade coincides with the consolidation of the social web, particularly social networks such as Facebook, microblogging platforms such as Twitter, Instagram, and that of the wikis, in a context of socioeconomic crisis that hinders or delays their insertion into adulthood. Other researchers call it generation 2.0, or Google, Facebook, Twitter, or WhatsApp generations. The digital culture of these young students is represented by their skills acquired with their peers in a self-taught way, along with those learned in their courses according to the characteristics of their population (Schlogl, 2022). These students regularly made intensive use of ICTs and networks, particularly during the period of the COVID19 pandemics. A study shows that most students of all ages without gender differences state that they prefer to use ICTs in class every day, that they like to use them, and that the activities performed with them have an impact on their learning (Area Moreira et al., 2015).

## 5.2 Application in a student environment and field studies

The student sample ($N$ = 114) comprised 5th/6th-semester Computer Technology Engineering students enrolled in the Analysis and Design of Software Systems course, organized in 23 teams, as shown in Table 1.

### 5.2.1 Challenge solution

The challenges of the course were chosen to make students aware of the problems of this sector of the population. For this reason, in the first phase of the implementation, which took place during 2018 and 2019, the students were instructed to propose solutions for part of the problems of the elderly,

TABLE 1 Students' sections that participated in the development of apps and online systems to provide support and services for elderly people.

| Section | Term | Number of teams | *N* |
|---|---|---|---|
| AMSS 1 | Spring 2018 | 4 | 18 |
| AMSS 2 | Fall 2018 | 4 | 23 |
| AMSS 3 | Fall 2019 | 4 | 21 |
| AMSS 4 | Spring 2020 | 2 | 9 |
| AMSS 5 | Fall 2020 | 5 | 26 |
| AMSS 6 | Spring 2021 | 4 | 17 |
| Total | | 23 | 114 |

using technology in free format. Table 2 shows examples of the proposed applications, where an image of the app, its name, the name (and color) of the student team that developed it, a brief description of the app, and the term when it was implemented, are included. Subsequently, in the second phase of the project implementation, during 2020 and 2021, Organizations and Civil Associations (OCAs) from the public and social sectors such as elderly asylums and, in general, organizations that attend or provide services to elderly people, were also invited to provide their opinions to enrich the new proposals. Table 3 shows examples of the systems developed in the second phase.

### 5.2.2 PjBL teamwork documentation

Students elaborated individual and group reflections made throughout the different phases of the project. When the project and the course were completed, students were asked for their individual and group reflections including their final conclusions and description of how the team members worked during the project.

- The initial expectations of the team
- Collaborative work within the team
- Distribution of work
- Partnerships
- Meetings
- Motivation
- Team integration phases
- Individual Contributions to group work
- Aspects of participant's co-evaluation
- Conclusion
- Collaboration aspects with professor
- Expectations
- Agreements
- Consultation meetings
- Conclusions
- Group phase general conclusions

## 5.3 Grounded theory

After applying the model and pedagogical design of PjBL methodology, and given the characteristics of the information sources used, a research design was carried out from a qualitative approach through the grounded theory method, whose purpose was to induce substantive theory related to learning, application, and the emergence of transversal skills and the pedagogical strategy of the course. To this aim, the empirical data extracted by means of the NVIVO software were used, from the corpus of two types of documents prepared by the students: (i) the initial internal work contract, and (ii) the group process, where the students record their reflections, experiences, processes and learning during the project, as mentioned previously. The answers, reflections, points of view, and comments written by each team work in their documents regarding their work process during the development of their projects were then analyzed using the methodology of the grounded theory, as discussed next.

## 5.4 Data collection

For this study, the main documents of the group process carried out by the students were collected, as described below. The phases of data collection process were:

1. Technique of Textual repetitions. This exploratory technique initially allows identifying those keywords, categories, and concepts explicitly mentioned or related to the concept "transversal competences" when an idea, an activity, or a process is frequently repeated in the referenced quotes and notes, which may mean that it represents a regularly recurring category.
2. Preparation, cleaning, correction of files and conversion from word and pdf formats to text file and organization in folders by semester and teams.
3. Data extraction, using the NVIVO version 12 software and through data mining using word search tools.
4. Database construction and cleanup.

### 5.4.1 The internal work contracts

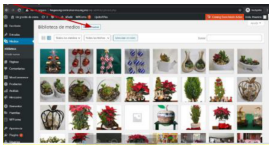
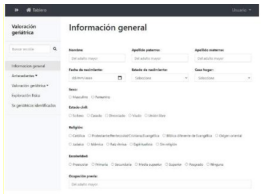
Due to the importance of collaborative work to solve complex projects, work teams of 4-6 members were formed from the beginning of the project. Each team had to establish its internal organization to maximize their chances of success in carrying out the project. For this reason, it was suggested that different roles and complementary support tasks were established during the project, in addition to distributing the technical work to be carried out. Therefore, each team was prompted to prepare an internal work contract that governed the operation and functioning of the team participants, which should include at least the following sections:

a) Student roles and support activities.
b) Means and forms of Communication.
c) Schedules of work and meetings.
d) Punctuality, attendance, compliance, and quality rules.
e) Rules for awarding rewards, recognition, and penalties.
f) Rules to maintain trust.

TABLE 2 Examples of apps developed in free format to improve the life quality of the elderly (First phase).

| Image | System name | Brief description | Term |
|---|---|---|---|
|  | Wisapp<br>Cyan team | Web application that allows older people to write their stories and life experiences | Fall 2018 |
|  | Pill coach<br>Purple team | To remind older people who are under some medical regimen to take their pills at the proper time of day. In addition, it is also designed for the relatives and/or caregivers of these people. | Fall 2018 |
|  | Portal containing useful information resources for the elderly<br>Orange team | To allow older people and specialists to recommend Apps or support sites, which must be validated by the administrator. | Fall 2019 |

TABLE 3 Examples of Web Systems developed for Organizations and Civil Associations (OCAs) that serve or provide services to the elderly (Second phase).

| Image | System name | Brief description | Term |
|---|---|---|---|
|  | Web page for Dauverre AC elderly asylum<br>Red team | Web application that helps provide the institution's mission, vision, daily activities, events, services, and social networks. | Fall 2020 |
|  | Online sales system "Una flor con causa" ("A flower with a cause") for asylum "Un granito de arena AC" ("A grain of sand AC")<br>Green team | Sales and administration system through a website that allows the sale of products, the generation of sales notes, as well as periodic sales reports. At the same time, it is projected that the system will allow the points of sale management. | Fall 2020 |
|  | Online digital marketing system "Una Flor con causa" ("A Flower with a cause") for asylum "Un granito de arena AC" ("A grain of sand AC").<br>Green team | Optimize communication and digital marketing strategies between association and client, cover the area of communication and dissemination of the project to achieve a greater scope, as well as expanding their client sector at the state level. | Fall 2020 |
|  | Electronic medical records system for asylum "Un granito de arena" ("A grain of sand AC")<br>Blue team | System to manage the clinical files of the elderly people of the asylum "Un granito de arena" ("A grain of sand") | Fall 2020 |

### 5.4.2 The reflective portfolio

Each student was asked to develop a reflective portfolio to allow them to be aware of the skills and knowledge they were acquiring during the project. Three main purposes were identified for student reflection:

(a) Know their status and identify their goals and needs.
(b) Know and explore their progress and conditions.
(c) Make them aware of their cognitive and educational progress, as well as their results and consolidation process.

### 5.4.3 The final documentation of the group process

At the end of the project, each team was asked to prepare a document to critically analyze their performance during the process, that is, their group process, in which the students should synthesize their individual and team reflections and write them on

both their individual portfolios and the team portfolio. This latter document allows integrating and rescuing all the memories of the team's collaborative work throughout the project. It includes the following aspects:

a. Semester expectations
b. Project planning aspects
c. Aspects of collaboration and internal organization of the team.
d. Collaboration with the project client
e. Agreements and meetings with the team teacher or tutor.
f. Conclusions

## 5.5 Study corpus

It was constituted by forty-six documents—23 internal teamwork contracts and 23 reflections of the group process—prepared by the students, which were part of the total documentation delivered by the teams where they documented the activities developed in the project during the semester.

The units of analysis were the paragraphs extracted from the substantive material: 46 separate documents in two files, 23 of internal work contracts and 23 of group process reflections, in which the student teams documented their reflections, experiences, activities, processes, learning and situations related to the initial expectations of the team, as well as the collaborative work within the team, aspects of collaboration with the teacher, and the general conclusions of the group process. From this information it was possible to obtain, identify and relate the categories associated with the transverse competences.

## 5.6 Data analysis strategies

The data analysis was carried out through the following phases, according to the methodology of the grounded theory (section 2.4):

1. *Automated Coding.* It allows identifying and grouping information by decontextualizing it, that is, extracting it from the original text, and on the other hand, it allows recovering a new recontextualized text. Once the data set has been prepared and selected, the software proceeds to the coding where it selects the words in context and references them in terms of frequencies in files and texts (Categories/Nodes)
2. *Open or native coding.* This procedure was also applied mainly when reading the two documents generated by the students and when cleaning the previous database of categories and subcategories that was generated in Excel.
3. *Axial and selective coding.* It was applied to group the most relevant topics that were identified by the percentage of the words with the highest frequency, the topics matrix, and the context analysis of the phrases associated with them. The word analysis, clustering, and word tree NVIVO tools were used.
4. *Delimitation of the theory.* Through data mining and the identification of the categories it was possible to listen and make visible the "voice in context" of engineering students in computer technologies, in relation to how, where, when, and with whom they acquire, use, and apply transversal skills. In addition, we also wanted to observe, in the analysis of the documents provided by the students, if the design and dynamics of the course allowed them to become aware of a relevant topic in Mexico, such as their conscientiousness with healthy aging and the reduction of their prejudices of ageism.

The most important results and analysis of this study are presented below.

# 6 Results and analysis

In the analysis of the documentation produced by the students during the development of their *Project,* documentation was found to play a crucial role in engineering courses that utilize Project-Based Learning (PjBL) implementation. First, this process contributes to the registration of innovative educational experiences and to the reconstruction of students' learning experiences, which are consolidated and validated to keep consistency and generativity (Libedinsky, 2011). Additionally, the documentation process allows students to apply and learn *soft skills or Transversal Competencies,* as discussed below. The documentation of educational experiences gives rise to the need to better understand how and why one thinks or acts in a certain way. In the same way, it allows us to reflect on the ways in which solutions to unresolved problems are found and to evaluate the impact of these strategies on the learning and evaluation of transversal competences. The following are some patterns that were observed in the students' documentation:

1. Knowledge Capture and Retention: Documentation allows students to capture and retain knowledge gained during the project.
2. Accountability and Transparency: Students can document their individual and group responsibilities, tasks, and progress.
3. Collaboration and Communication: Documentation facilitates collaboration and communication among project team members.
4. Evaluation and Assessment: Documentation provides a basis for evaluating and assessing students' performance and project outcomes.
5. Reflection and Learning: Documenting the project process and outcomes encourages students to reflect on their work.
6. Transferable Skills: Through documentation, students develop transferable skills that are highly valuable in professional engineering computing practice.
7. Professional Practice: Documentation aligns with the expectations of professional engineering practice.

In the following the students' reflections that emerge from the written documents produced by work teams in their PjBL portfolios are presented.

## 6.1 Internal contract

As mentioned before, *the internal contract document* is the phase of the project where the work team is integrated, defined, and built. Through this activity students apply, learn and develop essential *soft skills Competences* in the process of team formation, work organization, and the drafting of the document such as: collaborative work, oral, written and digital communication, as well as empathy. The establishment of operation rules, responsibilities, tasks, objectives and times for the development and delivery of the project with high quality standards become very relevant in the contract that students commit themselves to perform.

Figure 3 shows the histogram of the more frequent words or categories found in the 23 "Internal Contract" documents of the students' work teams. The five words (central categories) that represent the highest number of frequencies are: *team* (316), *work* (196), *project* (122), *members* (106), and *communication* (103). The corresponding word cloud diagram is presented in Figure 4, in which the main categories clearly emerge from the word cloud in four quadrants that show us the functions, activities, and actors related to the aspects that the students perform during this activity, showing the processes and contexts that can be associated with the transversal competences. The importance of teamwork to develop the project is clearly emphasized and presented as the axis in the central part of the diagram, which articulates the members of the team with the development of the projects through communication abilities and rules to successfully perform their tasks.

The four quadrants are:

1. *Team-work*. Working in a team allows for peer-to-peer learning and promotes the rise and growth of soft skills.
2. *Project-communication*. This quadrant shows the importance in the elaboration of the internal employment contract of the "competence of oral and written communication", which implies knowing what to say and how to say it based on the situation, the participants in the roles, and the interactions".
3. *Members-Member*. Quadrant shows as main subcategories the integration of the team distribution and definition of roles of the actors including the teacher, the definition of roles and times for the conclusion of the system. The main competency identified is "Teamwork Competency."
4. *Rules-Case-Task*. This is the quadrant that includes the operative part of the project development, including the persons, the users, the cases, the rules, the tasks, and the meetings.

Therefore, the internal employment contract links two central categories: the Work to be developed, and the integration and performance of the Team. Considering the quadrants and determined above, it is identified that students are developing the following skills: negotiation, flexibility, empathy, teamwork, and collaborative work.

## 6.2 Group process

Group process refers to the final reflection that each team performs at the end of the project on the group overall performance, on individual contributions and performance, and on the quality of the final delivery, emphasizing the most relevant successes and weaknesses through the project development.

The histogram of the more frequent words or categories included in the 23 group process reports elaborated by the students in their final reflections on the project is presented in Figure 5. The most frequent words are *team* (281), *work* (280), *project*

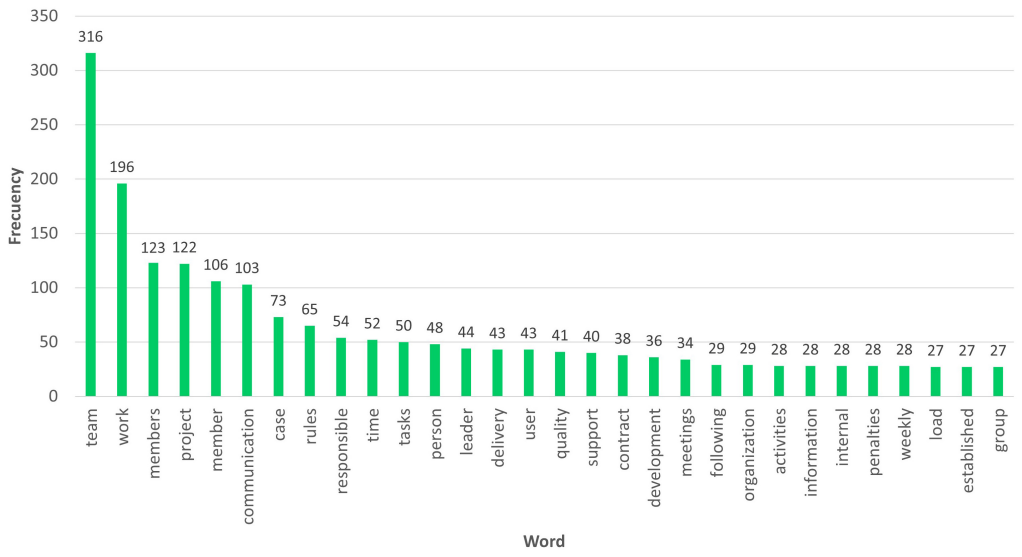



FIGURE 3
Histogram of the first 30 more frequent words.


FIGURE 4
Main categories and their categories related to the internal contract. First 50 words extracted from the 23 students reports.

(190), *members* (114), *development* (90), *communication* (73), and *member* (68). The corresponding word cloud is shown in Figure 6.

In the diagrams the central importance of teamwork collaboration among members to establish agreements, expectations, and motivation to develop the project is clearly prominent. The objective sought with the task can be achieved in a more efficient and enriching way thanks to the collaboration and contribution of the different members of the group in the team, which is mentioned frequently by the students. In these cases, it is understood that it is not possible to meet the proposed pedagogical objective by resorting to the work of a single person or to the simple sum of individual works. In the word cloud, it is also apparent the emergence of the six topics already identified in the histogram: *team*, *work*, *project*, *members*, *development*, *communication*, and *member*.

Several regions can be identified in Figure 6. The center of the quadrant is occupied by *work team*, which is connected to the *project* and to the *members*, who *communicate* and *meet* through the project *development*, including the *programing* part, and who *document* the *tasks*. In the figure two important relations can be identified:

1. *Members-communication*. This sector clearly reflects the importance given by students to the continuous communication among team members as well as with the professor and clients.
2. *Member- project development*. This points out the importance of programing skills in the team development of the project.

## 6.3 Advisory professor

In the group process document, students also reflected on their interaction and collaboration with the group teacher. Figures 7, 8 present, respectively, the histogram and the word cloud of the most frequent words or categories expressed by the students of the 23 teams that participated in this research, in the section *Aspects of collaboration with the teacher* of the group process document. According to Figure 7 the most frequent words are: *professor* (119), *project* (48), *expectations* (48), *agreements* (39), and *team* (32). In these graphics the professor had a central role as advisor supporting team collaboration, giving feedback along all the project development, from the beginning to its conclusion, helping defining expectations and agreements among team members. Professors used their experience to provide consultancies to supervise teamwork during the semester in the class or in specific tutoring meetings, giving students the required advice, support, and help, solving any doubts in the established dates. Students highly appreciated the support and accompaniment offered by their professors during the project development.

From the word cloud infographic in Figure 8, the triad of categories *professor*, *project*, and *agreements* are clearly depicted, which articulate the thematic quadrants related to *meetings*, *collaboration*, *expectations,* and *teamwork*. It can be seen that this triad of categories (*professor*, *project* and *agreements*) make up four thematic quadrants, where the professor was linked with various interaction functions and activities which allowed us to see in context and infer the various transversal competences that students were applying and acquiring in the interaction with the teacher, their teammates and customers or users. The *professor* was at the center articulating two arms (elements) that follow this category in mentions: the *project—expectations* arm and the *agreement*s arm. These arms delineate four thematic quadrants:

1. *Professor-project-expectation-advice-* In this quadrant the professor's role as advisor and accompaniment throughout the semester helping and supporting work teams is highlighted.
2. *Professor-team work-feedback*. In this quadrant the professor provided feedback to the teamwork using her experience to help teams to solve doubts to meet the requirements of the project and deliveries set by the clients.
3. *Professor-project- meetings*. This quadrant highlights the importance of the periodic meeting between the teams and the professor to provide various ways to solve project requirements and monitor students' progress.

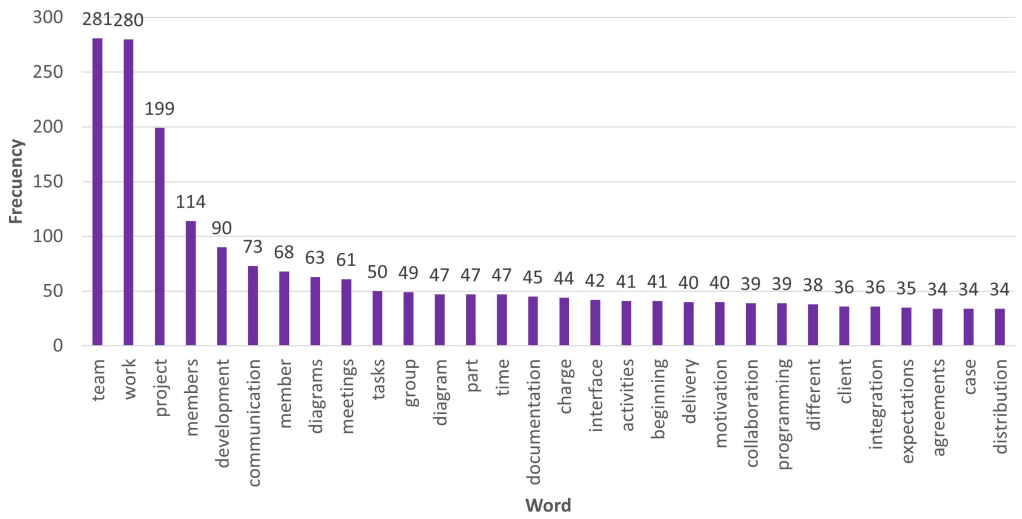



FIGURE 5
Frequency of the 30 more frequent words extracted from the 23 students reports.


FIGURE 6
The word cloud and infographic visually depict the triad of main categories team, work, and project, which form the basis of three thematic quadrants related to group process.

4. *Professor- project- collaboration*. This quadrant emphasizes the importance of the professor promoting student collaboration and communication to prepare timely appropriate deliveries. To this end, students met with her professor to agree, receive feedback, review expectations, and perform their collaborative activities.

Overall, the analysis presented in the text provides insights into the evolving role of the teacher and the meeting spaces in project-oriented learning. It highlights the importance of the professor's guidance, support, and pedagogical tools such as accompaniment and technological mediation in promoting experiential learning and the development of soft skill competences.

Based on the information provided, the collaboration and interaction between student and the advising professor seems to have fostered the development of several soft skills. Examples of the skills that can be inferred from students' texts are presented next.

1. *Communication:* The students engaged in communication with the advising professor through various means, such as face-to-face consultation or through digital communication tools as email, WhatsApp, and zoom meeting sessions. Effective communication skills were necessary to express their doubts, ask questions, and receive feedback from the professor. This collaboration likely helped students enhance their written, digital, and verbal communication skills.
2. *Collaboration*: The students worked as a group and had agreements with the professor following a consultations schedule. This required collaborative efforts and teamwork among the students to coordinate and organize their meeting effectively. Through this collaboration students likely developed skills such as teamwork, cooperation, and the ability to work collectively toward shared goals.
3. *Time Management:* The agreement to schedule consultations in advance indicates the importance

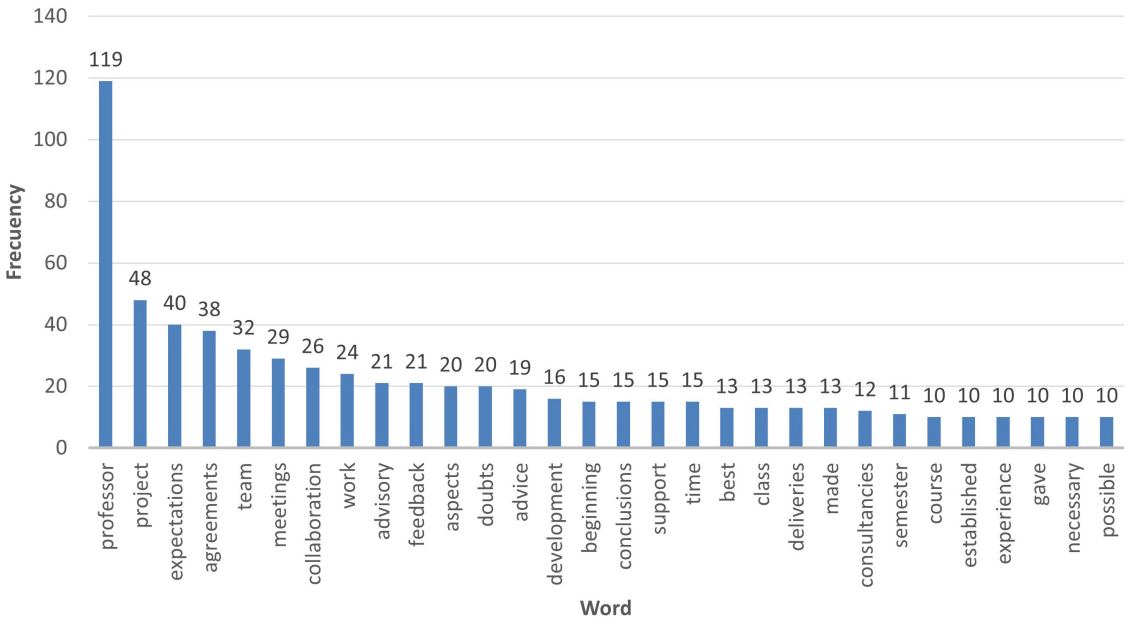



FIGURE 7
Frequency of the 30 more frequent words extracted from the 23 documents of the group process in the section aspects of collaboration with the teacher.


FIGURE 8
Word cloud for section *Aspects of collaboration with the teacher* of the group process document.

of time management. Students had to plan and allocate specific time slots for consultations with the professor, ensuring that each team had dedicated time. This collaboration likely encourages students to develop skills in prioritization, organization, and meeting deadlines.

4. *Problem-Solving:* The collaboration with the advising professor involved addressing doubts and receiving feedback on the deliverables. Students had the opportunity to engage in problem solving by presenting their challenges and seeking solutions through consultations. This likely helped them develop critical thinking skills, analytical abilities, and the capacity to identify and address issues effectively.
5. *Adaptability*: Students may have needed to adapt to the professor's expectations and guidelines for collaboration, such as scheduling consultations by email, WhatsApp and Zoom in advance. This required flexibility and adaptability and establishing an effective working relationship. Developing adaptability is a valuable soft skill that allows individuals to adjust to changing circumstances and work collaboratively with different people.

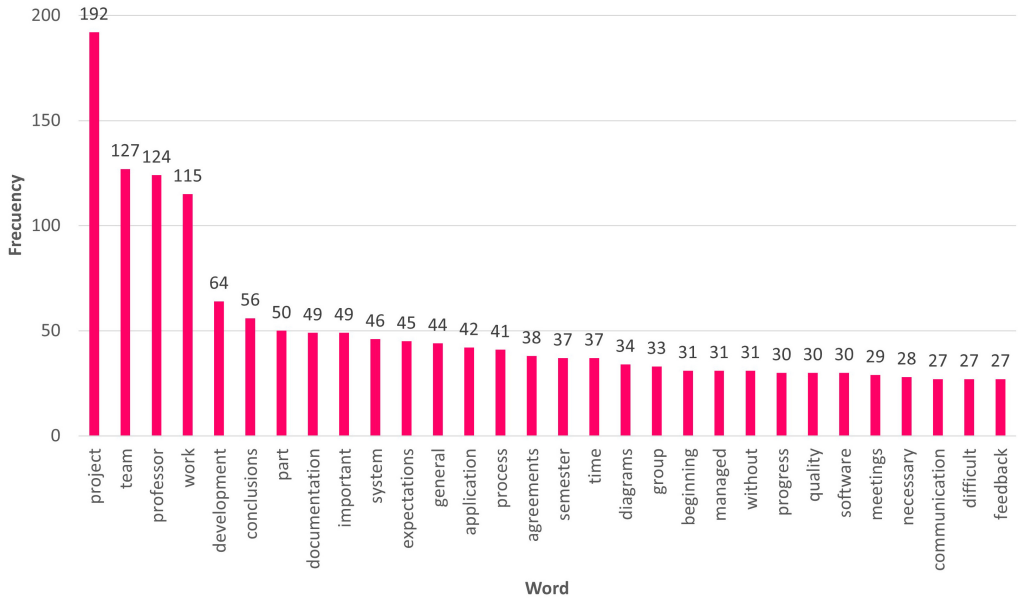



FIGURE 9
Histogram of the 30 most frequent words extracted from the 23 documents of the students' conclusions texts.


FIGURE 10
The word cloud and infographic visually depict the triad of categories *project*, *team*, and *professor*, in the students' conclusions.

### 6.3.1 Transversal competences convergence model

In summary, the collaboration between students and the advising professor likely facilitated the development of the transversal competences such as communication, collaboration, time management, problem solving, and adaptability. These competences are very valuable in academic and professional contexts and contribute to students' overall growth and success.

## 6.4 Students' conclusions

At the end of the term students had to write their final conclusions on their experience while developing their projects. These documents are discussed in this section. In a similar way for the previous documents, the histogram and the word cloud of the most frequent words or categories extracted from students' written documents are shown in Figures 9, 10, respectively. From Figure 9, the most frequent words extracted from students' conclusions are: project (192), team (127), professor (124), work (115), development (64), and conclusion (56). In the cloud diagram (Figure 10) three central categories are presented: *Project*, *Team*, and *Work*, which reflects the fact that the project-based learning model implemented in the Analysis and Design of Software Systems course clearly reveals the close relationship among these elements, as expected.

According to their final conclusions, students assign the main importance to development and on time delivery of the project with the appropriate documentation. The collaboration for efficient teamwork, communication among team members, support and communication with the professor are crucial elements to end with

a high-quality final project. Students also mention the relevance of establishing agreements among members during the process to fulfill the students' expectations, and to be able to end with important and valid conclusions during the project development. Furthermore, students highly value the role of the professor to provide them feedback and solve difficult problems during the semester. These findings support and complement the results that emerge from the discussions of the previous documents outlined above, that is, the internal contract and group process.

## 7 Discussion

Through project-based learning (PjBL) it is possible to break the gap between what students learn at university and what they need in the workplace. PjBL gives students the opportunity to engage in real-world problem solving and knowledge building in authentic professional contexts (Lavado-Anguera et al., 2024; Zhang and Ma, 2023).

In courses where PjBL has been implemented students' knowledge, strategies, and skills have been frequently measured mostly using instruments, namely, self-reported questionnaires, rubrics, tests, interviews, observation, self-reflection journals, and artifacts. While in several research students' perceived benefits and experience of PjBL have been measured by questionnaires, interviews, observation, and self-reflection diaries (Guo et al., 2020) great difficulty has been faced in measuring the competencies acquired by students, because they have usually been subject to the teacher's judgment.

Therefore, unlike other studies that are based on the evaluation of learning through grades, this research was conducted from a qualitative approach through the grounded theory method whose purpose was to induce substantive theory, related to the learning, application and emergence of transversal competencies and the pedagogical strategy of the course. Consequently, the development of soft skills has been extracted from the proper students' voices and reflections captured from their documentation while developing the project. In this regard, the analysis of the skills acquired by students in this work is directly derived from their own voices and not from the teachers' interpretation, which can be subjective.

According to the results obtained, through this study based on grounded theory, it has been possible to identify the most relevant language elements for the studies and thus infer the acquisition of transversal competencies in university students of computer engineering, developed through the PjBL technique, providing students with the benefit of experiential learning.

In the following, the research questions initially posed are addressed:

*(i) Can the internal work contract documents of the teams and group processes prepared by the students be considered evidence of the application, acquisition and appropriation of the transversal competences envisaged for this course?*

In this study, many of the conclusions obtained were drawn from the reflections of the students, expressed in their documentation of the portfolio of reflections that was developed throughout the course. The internal work contract of each team, the reflections in the group process, the collaboration with the teacher and the final conclusions of the work developed stood out. Through these reflections it was possible to infer the development of transversal competencies of the students.

Therefore, the internal employment contract linked two central categories: the Work to be developed, and the integration and performance of the Team. Considering the quadrants determined above, it was identified that students were developing the following skills: negotiation, flexibility, empathy, teamwork, and collaborative work. These competencies clearly refer to the collaboration and team working skills that students have developed while working with their projects, in agreement to those reported by other authors (Owens and Hite, 2020; Fajra et al., 2020; Granado-Alcón et al., 2020; Birdman et al., 2022; Guajardo-Cuéllar et al., 2022).

*(ii) What transversal competences are developed by the students in the course designed with the Project-Based Learning (PjBL) educational model through the development of the project (oriented to the thematic lines of healthy aging, prevention, and mitigation of frailty syndrome), emerging from the students' reflection documents: group processing, collaboration with the advisor professor, and final conclusions?*

In the group process document the central importance of collaboration in teamwork among members to establish agreements, expectations and motivation to develop the project was clearly highlighted. To achieve the objectives of the project the students had to show the collaboration and contribution competences of the different members of the group in the team.

In general, the analysis presented in the collaboration with the advisor provided insights into the evolution of the teacher's role and meeting spaces in project-oriented learning. It highlighted the importance of the teacher's guidance, support and pedagogical tools, such as coaching and technological mediation, to promote experiential learning and the development of transversal competences. It can be inferred that the transversal competencies that students were been able to develop were communication, collaboration, time management, problem solving and adaptability. These skills are very valuable in academic and professional contexts and contribute to students' overall growth and success.

According to their final conclusions, students attached the greatest importance to the timely development and delivery of the project with proper documentation. The cross-cutting competencies identified were collaboration for efficient teamwork, communication among team members, and support and communication with the teacher and were noted to be of great importance for finishing with a high-quality final project. All these competencies perfectly align with those required for twenty first-century engineering professionals, as reported in recent PjBL reviews (Guo et al., 2020; Lavado-Anguera et al., 2024; Zhang and Ma, 2023).

## 8 Conclusion and future work

The planned, systematic, and appropriate documentation during the development of the project by the students proved to be very valuable to infer the acquisition of transverse and disciplinary competences by computing engineers. In this research four types of documents were analyzed: (i) the *initial contract,* where students defined the agreements and policies to be respected by all team members during the project development,

(ii) the *communication with the advisor professor,* where students registered the conversations of the periodic interactions with their professor regarding their advances and difficulties encountered, and where they received timely feedback and suggestions to continue and improve the quality of their projects, (iii) the *group process*, where students made a deep reflexion of the complete learning experience, emphasizing outcomes, successes and drawbacks, and proposed alternatives for solving difficulties and suggested recommendations for future collaborative projects, and (iv) *students' conclusions*, where students reflected on their overall experience while developing their projects, underlying their main achievements, opportunity areas, and recommendation for future productive work.

From the voice of the students extracted in these documents it was possible to identify the development of several important transverse competences as: negotiation, flexibility, empathy, teamwork, collaborative work, responsibility, time management, problem solving, and adaptability, among others. All these competences are essential for computing engineering students and are required in their future professional fields.

As future work, it is envisaged to perform a study of the impact, usefulness, benefits, and extent of the online applications developed by the different students' teams to support and facilitate the activities of those people or publics in charge of taking care the elder people. In this regard, it will be essential to closely collaborate with these publics to improve, complement, or replace the applications according to their needs.

## Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

## Author contributions

JN: Conceptualization, Investigation, Methodology, Project administration, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. EO: Data curation, Investigation, Methodology, Software, Visualization, Writing – original draft. LN: Investigation, Methodology, Project administration, Validation, Writing – original draft, Writing – review & editing. JR: Funding acquisition, Resources, Supervision, Validation, Writing – review & editing.

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## Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

## Generative AI statement

The authors declare that no Generative AI was used in the creation of this manuscript.

## Publisher's note



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