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Project-based learning: Student performance and perceptions in a food industry engineering degree course

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ABSTRACT

The project-based learning (PBL) methodology was applied in a Food Technology course during the third year of a Food Industry Engineering degree at the University of Extremadura. The purpose of the research was to assess the effectiveness of PBL in this specific teaching field, evaluate the utility of rubrics, and determine the level of student satisfaction. A total of 22 students were tasked with participating in a group activity where they had to formulate, design, prepare, and present a food product to their peers and teacher. The students produced multiple deliverables and received feedback from the teachers. They also completed a final report and an oral presentation. The project was evaluated by teachers, peers (peer evaluation), and through self-evaluation using rubrics. A satisfaction survey and an analysis of strengths, weaknesses, opportunities, and threats were conducted after the completion of the PBL activity. The main findings indicated that PBL and rubrics were effective teaching and evaluation methodologies, respectively, enabling students to achieve scores above 8. Teacher evaluations were higher than the self-assessments, which were close to peer evaluations, indicating a high level of commitment on the part of students. Effective communication skills need improvement. Students viewed the activity positively, as it helped them comprehend the subject matter and proved valuable for improving teamwork, autonomy, and overall learning. In conclusion, PBL resulted in an engaging and effective learning experience that enhanced the understanding of food processing content and fostered the development of the skills and competencies necessary for a professional food engineer.

Contribution/Originality: The major contribution of this study is its use of PBL methodology and the use of self- and peer-assessments with rubrics as effective pedagogical techniques for enhancing learning. Additionally, its originality stems from the focus on the specific field, such as Food Technology, which has not been extensively explored in the literature.

1. INTRODUCTION

Project-based learning (PBL) is a teaching strategy in which students, organized into groups, develop projects. The objectives pursued using this methodology include, among others, integrating knowledge and skills from various areas, promoting autonomy, teamwork, development of critical thinking, and facilitating the development of both written and oral communication skills (Alfares, 2021). Furthermore, PBL offers several advantages over traditional teaching techniques as it increases student satisfaction with the learning experience, fosters a more

positive attitude toward the subject of study, prepares students for the workplace, allows for broader educational goals, and adapts to the pace of each student's learning (Martínez, Herrero, & De Pablo, 2010). In this regard, some studies have demonstrated that the PBL teaching strategy leads to higher academic performance in science studies (Kokotsaki, Menzies, & Wiggins, 2016).

2. REVIEW OF LITERATURE

Normally, the model for the development of PBL methodology can be outlined in several stages, such as 1) Preparation: the instructor or teacher introduces the project topic to the students and encourages them to discuss and ask questions; 2) Planning: the teacher determines how to gather and analyze information and assigns different tasks; 3) Research: students work individually or in groups to gather information from various sources; 4) Conclusions: students draw conclusions based on the analysis of the collected data; 5) Presentation: students are required to present their final work to the entire class; and 6) Evaluation: the teacher provides feedback on the students' work (Du & Han, 2016).

Rubrics are considered a useful tool to measure students' skill acquisition after engaging in a PBL activity (Diep, Thuy, Lai, Viet, & Chung, 2023). Furthermore, in research presented at the Engineering Education Annual Conference & Exposition by Saunders et al. (2003), the use of rubrics is described as a highly valuable tool for evaluating PBL outcomes. Rubrics outline the criteria that distinguish good work from poor work and can be used to promote and assess students' achievement of specific learning outcomes (Meng, Dong, Roehrs, & Luan, 2023). Additionally, rubrics assist students by providing clear criteria that can guide the development, review, and evaluation of their own work, a process particularly valuable when developing projects in a PBL environment (Guo, Saab, Post, & Wilfried, 2020).

Sattarova, Groot, and Arsenijevic (2021) indicated that students' satisfaction is a fundamental requirement for the successful implementation of the PBL methodology in classrooms. This is because the substitution of traditional teaching methods is only possible if students support and are satisfied with alternative methodologies. Several studies demonstrate a high level of satisfaction among students with regard to PBL, as it positively impacts their interest, grades, effort, teamwork, and skills (Oliveira & Cardoso, 2021; Sattarova et al., 2021).

Focusing on the field of Food Industry Engineering, research on the implementation of PBL has indicated enhanced learning processes and the subsequent fulfillment of employer requirements (Rivero-Pérez et al., 2015). PBL was used by Oliveira and Cardoso (2021) and San-Valero et al. (2019) to enhance the written, graphical, verbal, and non-verbal communication of Engineering students. In the context of Chemical Engineering, Ballesteros, Daza, Valdés, Ratkovich, and Reyes (2019) suggested the application of PBL to unit operations, and modeling and simulation courses, incorporating a collaborative project. As mentioned earlier, some general skills are acquired by students through PBL. The University of Extremadura has outlined a list of transversal competences that need to be monitored across its programs (see Table 1).

Table 1. Transversal competencies (TCs) for the food industry engineering degree at the University of Extremadura (code and description).

TC1 - Basic proficiency in ICT (information and communication technology).
TC2 - Providing knowledge and teaching–learning methodologies at different levels; collecting and analyzing existing information.
TC3 - Effective and efficient problem-solving ability, demonstrating principles of originality and self-direction.
TC4 - Critical thinking, analysis, and synthesis skills.
TC5 - Effective and efficient management skills with an entrepreneurial spirit, initiative, creativity, organization, planning, control, decision making, and negotiation.
TC6 - Capacity for autonomous learning and a commitment to knowledge and lifelong learning.
TC7 - Knowledge of the principles and methods of scientific and technical research.
TC8 - Ability to work in a team.
TC9 - Continuous concern for quality and the environment, occupational risk prevention, and corporate social responsibility.
TC10 - Properly working in a biological laboratory with biological material, including safety, handling, disposal of biological and chemical waste, and keeping annotated records of activities.

In this study, the development of the PBL methodology in the Food Technology course of the third year of the Food Industry Engineering degree at the University of Extremadura is described. A great effort in applying innovative educative technologies has been made in recent years, particularly at the School of Agricultural Engineering (Andrés, Petrón, Carrapiso, Morales, & Timón, 2023; Carrapiso, González, Petrón, Pérez-Nevado, & Gaspar, 2023; Poblaciones, García-White, & Marín, 2021). Studies of innovative education in Food Technology are more limited than other areas. Therefore, it is crucial to initiate new research studies to explore the implementation of PBL and discover innovative solutions to address the challenges confronting the agri-food industry.

This study aims to assess the utility of rubrics for both teachers and students in evaluating a project. Additionally, it seeks to determine the level of student satisfaction with PBL to consider its incorporation into the curriculum for future professionals in the agri-food sector.

3. METHODOLOGY

3.1. Contextualization and Participants

This research was conducted with 22 students (15 females and 7 males) enrolled in the Food Technology course that is taught in the second semester (from January to May) of the third academic year of the Food Industry Engineering degree program at the University of Extremadura, Spain. Food technology is related to food processing and transformation processes. This subject carries a weight of six European credit transfer and accumulation systems, and three classes of 60 minutes were delivered each teaching week.

The project described in this manuscript is expected to serve as a guide or reference for other courses in the abovementioned degree and other Engineering degrees offered at the School of Agricultural Engineering.

3.2. Research Design

The Official Quality Plan of the School of Agricultural Engineering, where the bachelor's degree in Food Industry Engineering is taught and approved by the National Agency for Quality Assessment and Accreditation, entails annual surveys (Google questionnaires) of both real and potential employers of graduates from the programs offered. The surveys ask about the most required skills for workers from the list of transversal competences at the University of Extremadura (see Table 1). The results of these annual surveys are published internally at the university, and it can be concluded that employers consider transversal skills to be those that workers need to significantly improve. Among these are written and oral communication skills and the ability to design, carry out, present, and defend a project. For this reason, the need to conduct this study was proposed.

3.2.1. PBL Activity Schedule

The PBL activity was conducted in several stages, following the model proposed by Du and Han (2016) with some modifications:

Stage 1: The teacher explains the project topic, forms working groups, and provides information on how to gather and analyze information.

Stage 2: Students work individually or in groups to collect information from various sources. Compilation of the first deliverable.

Stage 3: Feedback provided by the teacher.

Stage 4: Compilation of the second deliverable.

Stage 5: Feedback provided by the teacher.

Stage 6: Students manufacture the item food product in the Pilot Plant

Stage 7: Compilation of the third deliverable.

Stage 8: Oral presentation of the project to peers.

Stage 9: Evaluation of the project by teachers, peers (peer evaluation), and self-evaluation.

Stage 10: Student satisfaction survey.

As observed in Table 2, the activities (in the classroom or outside the classroom) were developed during the twelve weeks of the second semester. The estimated workload for students was 15–20 hours.

Table 2. Chronological schedule of the necessary stages to fulfil the project.

Stage	Second semester (week)												Deliverable
	1	2	3	4	5	6	7	8	9	10	11	12	
PBL explanation													-
Stage 2													#1
Stage 3													-
Stage 4													#2
Stage 5													-
Stage 6													-
Stage 7													#3 (Final report)
Stage 8													-
Stage 9													-
Stage 10													SWOT, Likert

Note: Deliverable #1: Food item to be manufactured and necessary ingredients, additives, and equipment.
Deliverable #2: Formulation and processing flow chart.
Deliverable #3: Report describing the processing carried out.
Deliverable #4: SWOT (Strengths, weaknesses, opportunities, and threats), "Likert".

3.2.2. PBL Activity Description

On the first day of the course, the purpose of the project, contents, competencies to develop, and sequence to be followed was introduced (see Table 2). The students were presented with the challenge of formulating, designing, preparing, and presenting a food product (meat, dairy or vegetable). The manufacturing of the food product was carried out in the Pilot Plant of the School of Agricultural Engineering. Students organized themselves into eight working groups, each consisting of two or three self-selected students. The students were asked to have an initial discussion to define team member roles (leader, information seekers, spokesperson, etc.). Professors provided resources and supplementary materials for the upcoming project (links to e-books, web sites, etc.). In addition to this, the only help given to the students was the food ingredients and additives, as well as the equipment, which was available at the school. They were also informed of the criteria to be included in the report to be submitted. Students were then dismissed to fulfil the learning task with the understanding that they would send their submissions (deliverables) to the teachers. The groups met independently outside of scheduled classes to produce the different deliverables and to develop their final products. The students conducted a literature search in various databases and in the resources prepared by the teachers. Using the gathered information, they prepared the different deliverables. Each submission received feedback on what was correct and what needed improvement. After the final submission of the project report, the groups explained to their peers and teachers how the food item was produced. The product itself was also presented in the final session. Finally, rubrics were used as assessment instruments. The assessment of the activity was performed by both the teachers and peers, along with self-assessment regarding the work completed by each student. Lastly, a satisfaction survey regarding the activity, along with a SWOT questionnaire (assessing strengths, weaknesses, opportunities, and threats), were conducted among the students using Google Forms.

3.2.3. Feedback on the PBL Deliverables by Teachers

In the development of the project report, which was done in multiple submissions, feedback was provided by the teachers. They informed the students about the work completed up to that point and offered guidance on areas for improvement. The different submissions that comprised the final report are as follows:

Deliverable #1: Novel food product to be manufactured, and necessary ingredients, additives, and equipment.

Deliverable #2: Formulation and processing flow chart.

Deliverable #3: Report describing the processing carried out.

Deliverable #4: SWOT, Likert (these deliverables did not need feedback).

3.2.4. PBL Activity Rubric

The assessment of the PBL activity and the achievement of competencies were carried out using a rubric presented to students simultaneously with the explanation of the activity (see Table 3). This rubric establishes the criteria for the development of the project report and its oral presentation. The rubric includes five criteria and 13 sub-criteria with three ratings (low, intermediate and high). The highest score rating is 10, which reflects the best and most positive evaluation. The criteria of this rubric were adapted from Martínez et al. (2010) and from the Valid Assessment of Learning in Undergraduate Education (VALUE) rubrics (https://www.aacu.org/value-rubrics) developed by the Association of American Colleges and Universities (Rhodes, 2010). Both teachers and students (peer assessment and self-assessment) evaluated the projects using this rubric as the instrument.

Table 3. Rubric for the evaluation of the PBL task.

Evaluated criteria	Weighting	Score ratings		
A. Written expression and work presentation.	20%	High (7–10)	Intermediate (4–7)	Low (0–4)
Organization and structure	5%	The structure and organization are suitable. The different sections are clearly distinguishable.	The structure, organization and clarity of the different sections could be improved.	The document is unstructured and disorganized. The different sections are incorrect or indistinguishable.
Writing and grammar	5%	The document is written in simple language and can be understood perfectly. The document does not have spelling or grammatical errors.	There are some grammatical errors. The document is understandable, although some parts could be improved. With a little more effort, it could have been better.	There are several misspellings, and the text is not easy to understand. The document is slipshod. It shows that the authors have not put much effort in. Colloquial expressions are used on a regular basis.
Tables and graphics	5%	The work is supported by carefully chosen, original tables and figures, which are correct (title, footnotes) and well numbered.	The work is supported by tables and figures, but some of them are not correct (title, footnotes) or well numbered and don't clearly explain the content.	The tables and graphics help little in understanding the content or are irrelevant. The titles and footnotes are not appropriate. They are not properly numbered. Low quality graphics.
Content	5%	It is evident that the work has been approached seriously. Provides comprehensive, accurate and relevant information. The depth of the work is very high for the set time.	The approach could be improved. The work is partially accurate, comprehensive or relevant. Based on a proper investigation. The depth of the work is moderate for the set time.	It is evident that the work has not been approached seriously. There are several parts that have been copied and pasted and without elaboration. The depth of the work is insufficient for the set time.
B. Methodology	20%	High (7–10)	Intermediate (4–7)	Low (0–4)
Approach .	10%	The approach is good. The procedures are well described and provide comprehensive, extensive and accurate information. The project could be easily reproduced.	The approach is good, although it admits some improvements. The procedures are not completely described and don't provide comprehensive, extensive and accurate information. The project could not be easily reproduced.	The approach is not good. The procedures are not well described, and they don't provide comprehensive and accurate information. It would not be possible to reproduce the project.
Description	10%	Different sections are explained comprehensively,	The explanation of the different sections need improvement.	The different sections are not comprehensive.

Evaluated criteria	Weighting	Score ratings		
		correctly, and concisely.		
C. Bibliography	10%	High (7–10)	Intermediate (4–7)	Low (0–4)
.	10%	All references are included, matching the text and formatted according to the indicated style. Based on an extensive and careful investigation.	Some references are not included or need to be formatted according to the indicated style. Based on an extensive and careful investigation.	Many references are not included or are not formatted according to the indicated style. It is evident that more extensive and careful investigation is needed.
D. Oral presentation	40%	High (7–10)	Intermediate (4–7)	Low (0–4)
.	10%	The presentation is clear and delivered with confidence, addressing fellow students.	The presentation is clear and delivered with confidence but not completely addressing fellow students.	The presentation is completely unclear and delivered with lack of confidence. Fellow students are not addressed at all.
	10%	Handles slides or any other media adeptly. Conveys enthusiasm about the topic.	Handles slides or any other media with relative proficiency. Conveys enthusiasm about the topic.	Struggles with slides clumsily. Does not convey enthusiasm about the topic.
	10%	The font type and size are appropriate and easily readable.	The font type and size could be improved to make the presentation easily readable.	The font type and size are not appropriate or easily readable.
	5%	The use of colors makes the presentation visually appealing and creative.	The use of colors and design could be improved significantly to make the presentation more appealing and creative.	The colors and design make the presentation visually unappealing and/or boring.
	5%	High-quality visual elements that enhance the listener's interest.	Medium-quality visual elements that enhance the listener's interest.	No visual elements that enhance the listener's interest.
E. Defense	10%	High (7–10)	Intermediate (4–7)	Low (0–4)
	10%	Precisely answer all questions posed by the teacher or fellow students regarding the topic.	The answers to the questions posed by the teacher or fellow students are not completely precise or accurate.	The answers to the questions posed by the teacher or fellow students are not precise or accurate.

3.2.5. Activity Grading

The final grade of the project was determined based on the teacher's evaluation (50%), self-assessment (10%), and peer evaluation (40%). The weight of this innovation activity on the global mark of the Food Technology course was 20%. Other classical assessment instruments, such as the final exam, laboratory activities, classroom activities, online questions, and questionnaires using Kahoot! were also considered in the final marks of the course.

3.2.6. Satisfaction Survey

Following the completion of the activity, a satisfaction survey was conducted with the students (see Table 4) as well as a SWOT questionnaire. These were collected on the last day of the course and were anonymous. Gender was not considered.

Table 4. Satisfaction survey items.

Items
The objectives have been clearly defined, and appropriate guidelines have been provided for the activity.
The activity has helped me better understand this part of the course.
The activity has been useful for enhancing teamwork, and the overall experience has been satisfying.
The benefits of the activity would have been the same if it had been approached individually.

Items
I consider the activity useful for improving my level of autonomy.
I have learned more from this activity than from other, more traditional activities.
This type of activity brings the students closer to the development of their future profession.
Overall assessment of the activity (minimum = 1; maximum = 5)

Note: A Likert scale from 1 (Strongly disagree) to 5 (Strongly agree) was used.

4. DATA ANALYSIS

The data analysis utilized SPSS 19.0 software (SPSS Institute Inc., Cary, NC). A descriptive analysis was conducted to compute the means and standard deviations of the measurements for each parameter. The general linear models (GLM) procedure was employed for a one-way analysis of variance. Significance was established at a threshold of $p \leq 0.05$. Percentage calculations from the data were performed using Microsoft Excel. The responses to the SWOT questionnaire were gathered from Google Forms and thoroughly reviewed.

5. RESULTS AND DISCUSSION

5.1. Evaluation of the Final Projects Using Rubrics

The marks of the final projects obtained from the rubrics used by teachers and students (peer evaluation and self-assessment) are presented in Figure 1.

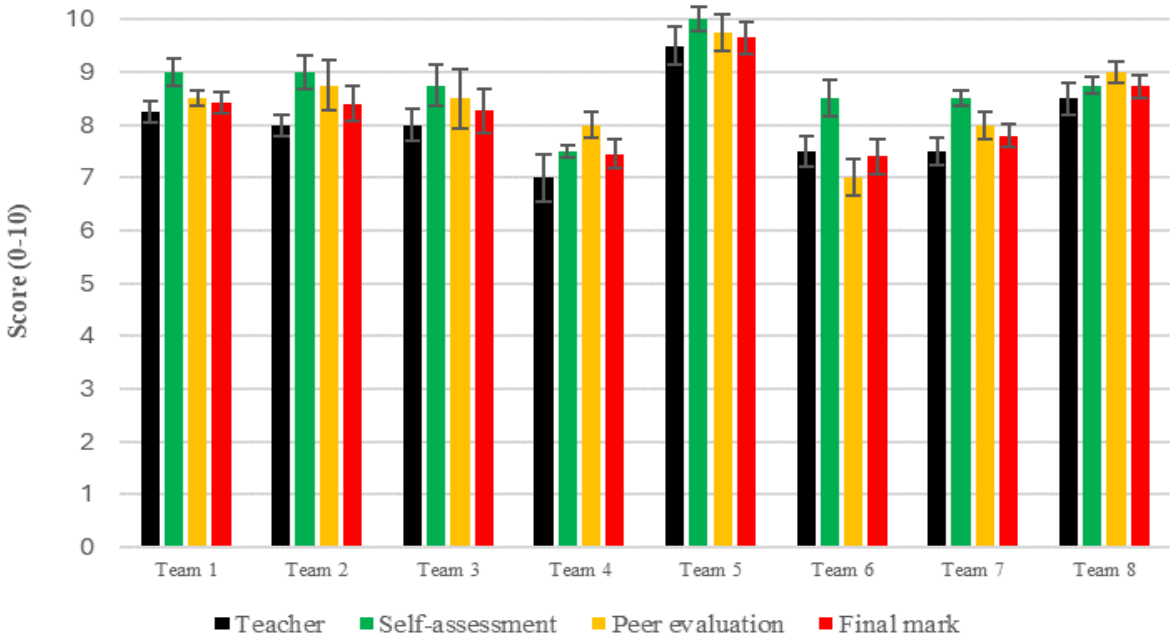

Figure 1. Evaluation of the final projects after the assessment using rubrics by teachers (n = 3), self-assessment (n = 2; n = 3), and peer evaluation (n = 22), as well as the final mark (Teacher: 50%; Self-assessment: 10%; Peer evaluation: 40%).

As shown in Figure 1, the final marks for the projects were above 8.0 except for groups 4, 6 and 7, which were only 0.5 points behind. The final marks were calculated based on the teacher's evaluation (50%), self-assessment (10%) and peer evaluation (40%). The evaluation of the project activity using rubrics (Figure 1) highlights the effectiveness of this methodology in student learning. These results also indicate the attainment of the knowledge and competencies outlined in the rubric. Numerous studies demonstrate the effectiveness of this methodology in university studies, particularly in engineering, technology, or sciences (Diep et al., 2023; Guo et al., 2020; Kokotsaki et al., 2016). In this regard, Meng et al. (2023) explained that the success of implementing PBL relies on the teacher's ability to effectively support, motivate, assist, and guide student learning. It is necessary to establish the purpose of the project, set clear and realistic objectives, and make decisions regarding the pace, sequence, and

content of learning. In this sense, the design of the activity proposed in this study meets the requirements for successful implementation of PBL in a Food Technology course. Guo et al. (2020) described the benefits of using rubrics in PBL methodologies for students, helping them understand learning outcomes, offering a means of support to develop skills and gain confidence, promoting self-directed learning, and providing opportunities for peer learning. Martínez et al. (2010); Kurnia, Liliasari, Adawiyah, and Supriyanti (2021) and Cifrian, Andres, Galan, and Viguri (2020) also concluded that the use of rubrics is essential for the effectiveness of PBL experiences in engineering and food courses.

The highest project scores were achieved through self-assessment of the project work (values above 9.0). In all cases, teacher evaluations consistently exceeded student evaluations. In addition, peer evaluation values were closer to those of the teachers in comparison to self-evaluation. A high correlation between teacher evaluation and peer evaluation was also found by Dahal, Luitel, Pant, and Rajbanshi (2022). Differences in the evaluations (teacher, self, and peer) were not statistically significant in general in this study ($p > 0.05$). However, the students tended to overestimate their work. In this sense, the feedback provided by the teacher during the project's development should have avoided this issue, since Duffrin (2003) observed that feedback encouraged self-assessment, aiding students in regulating their own learning and improving the process in a Food Science course. Coincidentally, in a study conducted by Liu, Lin, and Yuan (2002), self-assessment grades were significantly higher than those of the peer evaluation, and these were higher than those of the teacher's evaluation. In this study, peer evaluation was lower than self-assessment and closer to the teacher's marks. The results could indicate a higher level of commitment and responsibility for the task on the part of students who, despite knowing their peers, engaged in significant critical reflection when evaluating the presented work. Elawar and Corno (1985) also demonstrated that teacher assessment, when coupled with feedback, resulted in higher quality work. Self-assessment is viewed as an integral part of the learning process and is also valued for its usefulness to students when they enter their professional lives in the field of Food Engineering, as stated by Reitmeier and Vrchota (2009), and helps students improve their skills in the long term (Wiggins, 1998). Kitsantas and Baylor (2001) found that students achieved higher grades when teachers used self-assessment. Additionally, some sources believe that the self-assessment process enhances students' perception of instructor interest and concern regarding themselves and their classroom success (Mentkowski et al., 2000). However, the results obtained regarding the different marks from teachers and self-evaluation should be considered and the feedback process revised in forthcoming studies to improve the consistency of evaluations from different agents.

Fuentes and Villalobos (2013) investigated the effectiveness of PBL using self-assessment and peer evaluation compared to a traditional method, showing that the group using PBL had a more positive attitude toward the learning experience, emphasizing teamwork, cooperativeness, and critical thinking. The use of peer evaluation and self-assessment in the evaluation of PBL reinforces student learning. In this regard, some studies demonstrate the positive effect of using all three types of assessment (teacher assessment, peer evaluation, and self-assessment) on student learning (Ozogul, Olina, & Sullivan, 2008). Self-assessment develops critical thinking, enabling students to take a more active role in learning (Davies, 2002). Furthermore, the Institute of Food Technologists recommends using self-assessment tools to determine the achievement of course and program goals (IFT, 2023). According to Liu et al. (2002), peer evaluation can increase the time students dedicate to the activity and their engagement and responsibility for the task. Furthermore, comparing one's own work with that of peers contributes to the development of self-assessment competence (Topping, Smith, Swanson, & Elliot, 2000).

5.2. Evaluation of Effective Communication

The specific competence in effective communication (written report and oral presentation and defense) was also measured using rubrics. Table 5 shows the evaluation results for the rubric criteria. These results were produced only from the teacher assessment.

Table 5. Teachers' evaluation of the communication skills of students.

Evaluated criteria	High (7–10)	Intermediate (4–7)	Low (0–4)
Written expression and work presentation			
Clear and suitable organization and structure	50%	50 %	0%
Coherent and correct writing, without spelling or grammatical errors	0%	100 %	0%
Tables and graphics are original and appropriate	80%	20 %	0%
Oral presentation			
The presentation is clear and delivered with confidence, addressing fellow students	15%	85 %	0%
Handles slides or any other media adeptly. Conveys enthusiasm about the topic	18%	82 %	0%
The font type and size are appropriate and easily readable	18%	82 %	0%
The use of colors makes the presentation visually appealing and creative	18%	82 %	0%
High quality visual elements that enhance the listener's interest	0%	100 %	0%
Oral defense			
Precisely answers all questions posed by the teacher or fellow students regarding the topic	81%	19 %	0%

Students demonstrated intermediate written and verbal communication abilities in general. In terms of communication competence, there were notable variations based on whether the assessed skill was oral or written. Most students demonstrated intermediate-level written communication skills, indicating that the students should improve in this area. It should be highlighted, however, that 80% and 50% of students respectively achieved a high-level competency on tables and graphics criteria and organization and structure criteria. This indicates that the students had understood and followed the instructions given to them by teachers. Oral presentation skills require improvement among students, though a small percentage (15%–18%) displayed a high proficiency. It must be underlined that these are third year students. The results emphasize the need to include more activities to practice written and oral skills. However, up to 81% of students achieved an excellent result for the last criteria (they precisely answered all questions posed by the teacher or fellow students regarding the topic). These values suggest that the students have correctly learned the contents and procedures in relation to the developed project.

5.3. Evaluation of Student Satisfaction

Upon completing the activity, a satisfaction survey was administered to the students (see Figure 2).

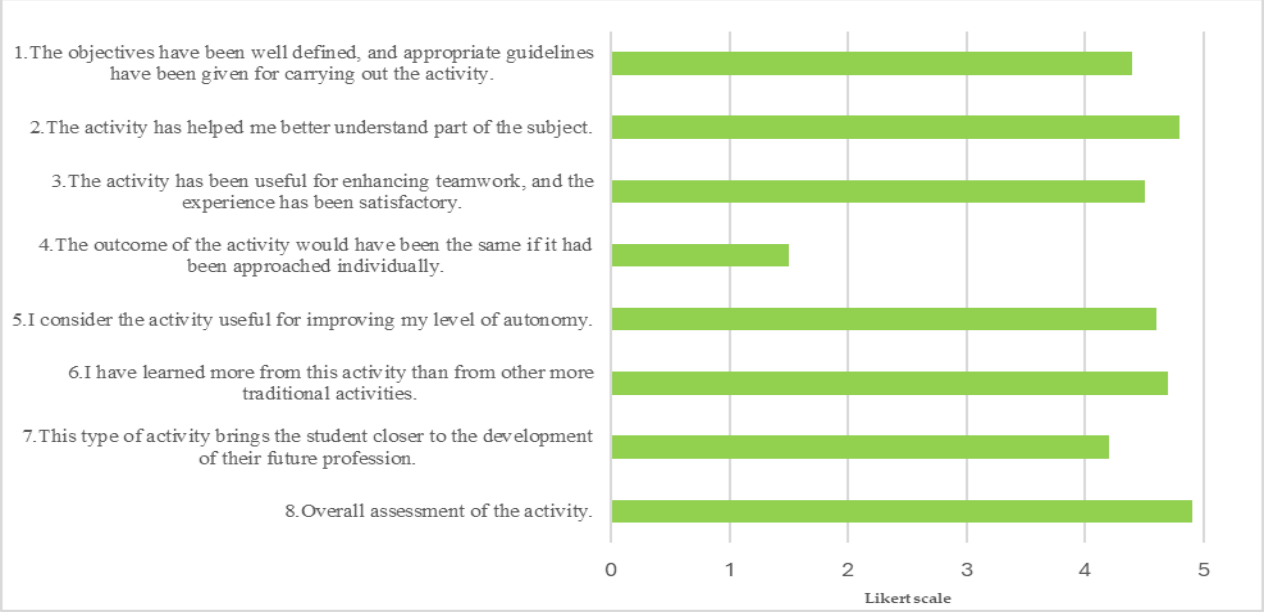

Figure 2. Student satisfaction survey for the project activity (1 = Strongly disagree, 5 = Strongly agree).

As depicted, students positively rated the activity, giving it a satisfaction rating of 4.9. The activity helped them better understand the contents of the course and was useful for enhancing teamwork, autonomy, and learning, with satisfaction scores above 4.0 and close to 5.0. Additionally, when the students were asked if "the benefit of the activity would have been the same if it had been approached individually," they disagreed (on a satisfaction rating scale of 1–5), highlighting the utility of the PBL methodology when working in groups.

The students' experience with the food technology project in this study was encouraging. Numerous studies demonstrate the satisfaction of students with PBL as it positively impacts their interest, grades, effort, teamwork, and skill improvement (Oliveira & Cardoso, 2021; Sattarova et al., 2021). As indicated by Sattarova et al. (2021), student satisfaction with the implementation of PBL methodologies is a prerequisite for effective implementation. The satisfaction survey conducted with the students in the Food Technology course were highly satisfied with the proposed PBL activity, with an overall satisfaction score of 4.7. In prior studies, factors such as insufficient time, overwhelming workloads, and inadequate mentoring and guidance have been recognized as obstacles for undergraduate students when it comes to participating in projects (Amin et al., 2012; Burgoyne, O'Flynn, & Boylan, 2010). Additionally, students' satisfaction scores were above 4.0 for the objectives set, understanding of the subject, teamwork, and the degree of autonomy acquired, in concordance with Boss and Krauss (2022).

For "the benefit of the activity would have been the same if it had been approached individually," students disagreed (score = 2.0), indicating that the PBL activity was more suitable when approached as a team. As previously mentioned, Fuentes and Villalobos (2013) indicated better academic results and a higher degree of student satisfaction when PBL methodology was used compared to the traditional method. Sikhakhane, Govender, and Maphalaa (2020) suggested that learning using PBL methodologies should be considered collaborative. Collaborative learning is crucial for developing competencies in a real-life problem-solving context, making students more independent and autonomous and creating a healthy and environment in the pursuit of the best solution.

An examination of the open-ended responses to the SWOT questionnaire provided further insights into the food technology project (see Table 6).

Table 6. Students' feedback on the food technology project and their overall experience.

What I liked best about this activity:
The teacher explained what we had to do and how
It enhanced my comprehension of the knowledge I have acquired
Discussing an issue with a friend help me to better understand the contents
From now on, whenever I purchase or consume a food product, I make an effort to consider the stages of processing and the ingredients used
I have become more proactive, which I will apply in my future courses
What I disliked most about this activity:
I am not used to writing texts and I found it difficult to express myself
Sometimes I felt frustrated because I did not know what information or procedure to follow among those found in the bibliography
I invested a lot of time, and it was sometimes difficult to study other subjects
I was hoping for a higher final grade
I liked this activity, but I would rather revert to memorizing
Strategies to improve the course:
Provide a wider range of ingredients, additives and equipment to increase the options of food items
Reduce the workload through synchronizing with other subjects

Students faced various limitations within the context of PBL, encompassing the challenge of transitioning from passive to active learning and assuming personal responsibility for knowledge construction. Students' complaints were related to the additional time invested in the activity, the difficulty in synchronizing with other courses, the effort required for writing and self-expression, and the selection of accurate information. However, they did not

encounter difficulties with engagement within groups. These comments align with the need to enhance written communication skills, as discussed in section 3.2.

Similarly, the teachers encountered several constraints when implementing PBL in this context. These constraints encompassed challenges associated with the acceptance of changes by students, the extra workload that the continuous feedback sessions required, and difficulty synchronizing with other courses.

It is worth noting that these limitations, as identified by both teachers and students, are consistent with findings in existing literature pertaining to the implementation of PBL in higher education programs, as documented by Oliveira and Cardoso (2021).

6. CONCLUSIONS

In conclusion, the implementation of the project-based learning methodology in the Food Technology course of the 3rd year of the Food Industry Engineering degree has proven effective in achieving the objectives outlined in this study. It has prepared students to tackle the manufacturing of a food product, giving purpose to the PBL experience and resulting in an engaging and effective learning experience that enhanced their understanding of the subject. However, communication skills, particularly written communication skills, need improvement. Even though the consistency of evaluations from different agents was notable, the feedback process should be revised in forthcoming studies to enhance it. The students viewed the activity positively despite the increased time and effort invested. Consequently, it can be concluded that the PBL methodology can serve as a valuable tool in this field of higher education to foster the development of the skills and competencies necessary for success in project completion and the application of knowledge in practical situations.

7. IMPLICATIONS

Several implications emerged based on the research findings: (i) further research could be conducted regarding the views of Food Engineering students regarding the benefits of using PBL; (ii) the feedback given to students should be investigated in forthcoming studies to enhance it considering its crucial importance in learning process; (iii) communication skills, particularly written communication skills, need enhancement; and (iv) PBL can be a valuable methodology to achieve improvement along with other transversal skills necessary for successful projects and the application of knowledge in practical situations in the agri-food sector, since these competencies are highly demanded by the industry.

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