The Impact of Project-Based Learning on the Development of Statistical and Scientific Skills: A Study with Chilean University Students from the Faculty of Health Sciences

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Abstract: This study investigates the impact of Project-Based Learning (PBL) with an emphasis on statistics on 26 Kinesiology students from a prominent Chilean university. A mixed-methodological approach was employed for the qualitative and quantitative analysis of data collected through surveys, supplementary interviews, and performance evaluations of these students. Furthermore, group grades during the project execution were examined. The correlation between academic performance and the perception of learning through this method was explored. The results indicate a generally favorable assessment of PBL, emphasizing its contribution to the development of statistical and scientific skills, as well as improvement in academic performance,

with the option to incorporate additional methods to cater to different student needs. It is concluded that PBL is a potential pedagogical strategy that promotes active engagement in learning and the development of practical skills relevant to health sciences students in Chile.

Keywords: Project-Based Learning, Statistics, University Student, Kinesiology, Student Perceptions, correlation

INTRODUCTION

In recent years, the higher education system in Chile has experienced significant growth, reflected in both the diversity of its academic offerings and the number of students seeking a university education (López et al., 2020). It is particularly noteworthy that there has been an increase in students choosing medicine, dentistry, and health science careers, making these fields some of the most sought-after in Chilean universities. According to recent data, a considerable percentage of aspiring higher education students in Chile opt for health-related careers as their first choice (Bordón et al., 2020).

This remarkable increase in the preference for health-related careers underscores the urgency of comprehensive and up-to-date academic training. This training should not only encompass the specific knowledge of each discipline but also equip students with the necessary skills to handle and analyze complex data. In this regard, statistical literacy becomes a crucial element of higher education, especially in health-related fields (De la Hoz et al., 2021). This need is further emphasized by the challenges posed by the interpretation and management of data in an increasingly information-driven world that relies on evidence-based decision-making.

Recognizing the importance of statistical literacy in health disciplines, we are faced with a contemporary challenge in higher education: ensuring that this training is effective and relevant. In the current context, competence in these areas is not only essential for academic development but also for practical application in various professional scenarios. It enables students and professionals to structure, interpret, evaluate, and communicate vital information related to these concepts and address complex and uncertain situations (Gal, 2002, 2005). However, current educational reforms have shortcomings in the teaching of these areas due to the lack of consensus on the appropriate pedagogical approach (Danä & Taniåžli, 2018; English, 2013; Kaplan & Thorpe, 2010; Sharma, 2017; Shaughnessy, 2007). To overcome this challenge, it is crucial to adopt a multidimensional perspective on statistical literacy, linking it to contemporary sociocultural and environmental issues, integrating data, and using methodologies such as project-based learning to promote interdisciplinary approaches.

Project-Based Learning (PBL) has established itself as a valuable and increasingly popular educational approach in various academic fields, including health sciences (Sáiz-Manzanares et al., 2022). This pedagogical method, which emphasizes active and student-centered learning, offers a unique opportunity to integrate theory and practice through real and relevant projects (Guo et al., 2020). In the context of teaching and learning statistics, PBL not only facilitates the

understanding of complex statistical concepts but also promotes critical skills such as analytical thinking, problem-solving, and teamwork (Farrell & Carr, 2019).

The importance of PBL in teaching applied statistics to health sciences is gaining growing recognition. This recognition stems from PBL's effectiveness in integrating theoretical learning with concrete practical applications, a crucial competence for future healthcare professionals (Davidson et al., 2019; White, 2019). Through PBL, students have the opportunity to analyze real data, address contemporary public health issues, and develop evidence-based solutions. This approach not only enriches the educational experience with relevant practical applications but also equips students with the necessary skills to understand and process health data. These competencies are essential for making informed decisions in their future professional practice (Dierker et al., 2018).

The relevance of this study lies in several key aspects. First, as healthcare sciences evolve rapidly, future professionals must be equipped with robust practical and analytical skills, something that PBL can significantly facilitate (Elkhamisy et al., 2022). Second, understanding students' perceptions of PBL can provide valuable information for educators and curriculum designers, enabling adjustments that enhance teaching effectiveness (Elsamanoudy et al., 2021). Furthermore, studying these perceptions helps identify potential barriers and facilitators in the implementation of PBL, ensuring that the approach is as beneficial as possible for student learning (Mitchell & Rogers, 2020).

This work is also justified by the need to align teaching methods with the demands of the healthcare sector, which increasingly requires professionals capable of interpreting and applying statistical data in clinical and research settings (MacDougall, 2020; Larson, 2023). By understanding how Chilean university students perceive and engage with PBL in health-related statistics, this study aims to contribute to the development of educational practices that are not only theoretically sound but also relevant and applicable to the current professional context (Davidson et al., 2019).

The present study aims to investigate the impact of PBL on students, with a focus on statistics in Kinesiology. To achieve this objective, two specific objectives (SOs) have been established:

- SO1: Evaluate the perceptions of Kinesiology students regarding PBL.
- SO2: Assess the impact of PBL on the academic performance of Kinesiology students.

Literature Review

PBL is an innovative pedagogical approach that has gained ground in various academic areas, including statistics and health sciences (Davidson et al., 2019; White, 2019). This method focuses on active and collaborative learning, where students engage in projects that require the application of knowledge and skills in real or simulated contexts (Lai, 2021).

In the field of applied statistics in health sciences, PBL emerges as an effective tool to foster a deep understanding of statistical concepts and their practical application. According to Mujumdar et al. (2021), PBL facilitates the integration of theoretical learning with practical applications, which is essential in disciplines like statistics where the abstraction of concepts can be challenging

for students. Additionally, Huang et al. (2023) emphasize that PBL in statistics not only enhances conceptual understanding but also develops critical skills such as data analysis, problem-solving, and teamwork.

In the health sciences, PBL provides an opportunity for students to experientially grasp the importance of statistics in their future professional practice. Dierker et al. (2018) underline that through PBL, students can analyse real health data, tackle contemporary issues, and develop evidence-based solutions. This approach is crucial in preparing future healthcare professionals for making informed decisions based on data analysis. Pilot et al. (2023) assert that PBL enriches the educational experience and equips students with essential skills for interpreting and applying statistical data in clinical and research contexts.

Furthermore, the literature suggests that PBL can significantly enhance student engagement and motivation. Xiao et al. (2019) and Pilot et al. (2023) indicate that PBL engages students more meaningfully than traditional teaching methods, as it allows them to see the direct relevance of what they learn in real-world scenarios. Davidson et al. (2019) add that this methodology promotes better knowledge retention, and a deeper understanding of how statistical concepts are applied in the field of health.

Previous Studies on Student Perceptions in Similar Contexts

Understanding student perceptions regarding PBL applied to statistics in health sciences is crucial for evaluating and refining this pedagogical method. Research conducted over a decade ago, such as the studies by Freeman et al. (2008) and Dierker et al. (2018), already delved into how health sciences students experienced and valued PBL in statistics, linking it to their disciplinary education. These studies have provided valuable insights for educators and curriculum designers. However, scientific exploration on this topic continues to evolve, expanding our understanding of the effectiveness and implications of PBL in health sciences education.

A key study by Davidson et al. (2019) focused on how PBL influenced the motivation of undergraduate students in the medical faculty. They discovered that PBL increased students' interest in statistics by providing them with a clear and applicable context, thereby demonstrating their commitment and motivation towards learning.

On the other hand, Si (2020) centered on the perception of 40 second-year pre-medical students regarding PBL as a tool to develop analytical and problem-solving skills. They found that students highly valued PBL for its ability to simulate real-world professional challenges, allowing them to better understand the applicability of statistics in the field of health.

Furthermore, the work of Elsamanoudy et al. (2021) highlighted students' perception of PBL as a means to enhance collaboration and communication within multidisciplinary teams. Students indicated that PBL provided them with a platform to collaboratively discuss and analyse data, emphasizing the relevance of teamwork – an essential element in health sciences.

Another significant study conducted by Pilot et al. (2023) explored the attitudes of health sciences students towards PBL in statistics. The results revealed that, although students were initially sceptical, over time, they recognized the value of PBL in applying theoretical knowledge, using

statistics in real-life situations. This finding underscores the importance of students gradually adapting to innovative pedagogical methods.

Collectively, these studies emphasize that student perceptions of PBL in statistics applied to health sciences are generally positive, highlighting its utility in developing practical, analytical, and teamwork skills. However, they also point out the need for an adaptation period for students and the importance of a pedagogical approach that effectively integrates theory and practice.

On the other hand, despite significant advances in understanding PBL in statistics applied to health sciences, there are limitations in previous studies that this manuscript seeks to address. While previous studies, such as those by Davidson et al. (2019) and Si (2020), provided a fundamental understanding of how students perceive PBL, these investigations have mainly focused on specific contexts of medical students, which may not fully reflect the diversity of experiences and perceptions in different educational settings within health sciences.

Additionally, the adaptation and response of students to PBL in the Chilean context, a scenario with distinctive educational, cultural, and social characteristics, have been explored to a lesser extent. Despite research like that of Elsamanoudy et al. (2021) emphasizing the importance of teamwork and collaboration in PBL, there remains a lack of studies focused on how these aspects are experienced and perceived by students in Chile.

In response to this gap, this study seeks to investigate the perceptions of Chilean university students in Kinesiology regarding PBL from the perspective of statistics. It focuses on exploring how Kinesiology students, distinct from medical students, perceive and adapt to PBL, as well as how these perceptions influence their motivation and approach to learning.

Method

In this study, a mixed-methods approach is adopted, which combines quantitative and qualitative methods. This methodological choice aims to deepen the understanding of the phenomena under investigation. As Almeida (2018) points out, mixed-methods methodology is particularly effective in gathering essential data and enhancing thematic analysis, thus providing a more comprehensive and detailed insight. This approach is suitable for the context of this study, which focuses on Chilean university students in the health sciences and their experience with PBL. The integration of these mixed methods holds the promise of significantly enriching our understanding of the topic and supporting the development of future educational interventions tailored to their needs and specific contexts.

Context and Participants

In this research, we had the participation of 26 Kinesiology students from a university located in the central region of Chile. These participants, with an average age of approximately 19.7 years, were enrolled in a mathematics course that is a mandatory part of their professional curriculum. This course required students to carry out a research project related to issues in their field of study, using statistical techniques to analyse the collected data, develop evidence-supported conclusions, and suggest theoretically backed solutions.

On the other hand, an interview was also conducted with the teacher in charge of the mathematics course to inquire about her experience with PBL-based teaching. This teacher has 20 years of teaching experience in mathematics, and statistics and probability. In this context, her professional perspective offers a broader understanding of PBL implementation.

It is worth noting that, although this study was a common activity for all students in the mathematics courses, we only included in our sample those participants who gave their explicit authorization to disclose this information. Participation in the research was entirely voluntary and was conducted after obtaining their authorization and consent.

Teaching and Learning Strategy Used in the Course

During the first semester of the year 2023, which spans from March to July according to the Chilean educational system, the responsible teacher implemented the PBL method in the mathematics course. This approach aimed to make the teaching and learning process of mathematics, which includes the use of statistics, more closely connected with the topics of kinesiology. To achieve this, one hour per week was dedicated to providing essential guidance and instructions for each stage of the project (see Table 1). During these sessions, the teacher explained the rubric used to assess both the reports and oral presentations of the students, and carefully reviewed the reports submitted by each group.

Table 1. *Week and phase distribution of the PBL.*

Week	Phase	Detail	Assessment
1 2 3	*Phase 1: Statement of the problem and choice of physical activity to analyze.*	Students should choose a physical activity they want to analyze (for example, running, jumping, throwing a ball, etc.) and ask a research question that allows them to analyze human movement in that activity.	Progress monitoring 1
4 5 6	*Phase 2: Data collection.*	Students must collect data on the chosen physical activity. They could do this by filming a video of someone doing the activity or by directly observing someone doing it.	Progress monitoring 2
7 8 9	*Phase 3: Data analysis.*	Students will analyze data using vectors and mathematical functions. For example, they could use vectors to analyze the direction and magnitude of motion, and functions to analyze velocity and acceleration.	Progress monitoring 3
10 11 12 13	*Phase 4: Presentation of results and conclusions.*	Students must present the results and conclusions of their research. They could do this through a written report and an oral presentation.	Oral presentation and final PBL report
14 15	*Phase 5: Reflection on the research process.*	Students will be asked to reflect on the research process and share what they have learned about the use of mathematics in kinesiology.	--

This project is designed for students to apply the mathematical-statistical concepts they have acquired during the course to real and relevant situations related to their careers. Furthermore, it provides them with an opportunity to develop skills in research, data analysis, and presentation of results. Students have the option to choose from the topics suggested by the teacher, which can be found in Table 2, or alternatively, propose their own topic that aligns with the established guidelines and characteristics.

Table 2. *Topic proposals for the PBL.*

Topic	Detail
1	Analysis of the movement of specific athletes, such as marathon runners, basketball players, gymnasts, etc.
2	Study of movement in different stages of human development: infancy, childhood, adolescence and old age.
3	Research on movement in people with particular physical conditions: injuries, disabilities, chronic diseases, etc.
4	Comparative analysis of movement in various sports, including football, basketball, swimming, volleyball, among others.
5	Examination of movement in daily activities such as walking, running, lifting objects, climbing stairs, etc.
6	Study of movement in different physical therapy approaches: occupational therapy, physiotherapy, rehabilitation, etc.
7	Analysis of movement in cultural and traditional practices: folk dance, martial arts, yoga, among others.

Techniques and Instruments

To achieve the research objective of this study, various data collection techniques and tools were implemented. Firstly, a survey was administered to all participants to gain a general understanding of their perspectives. Additionally, supplementary interviews (with some students and the teacher in charge of the mathematics course) were conducted to delve deeper into the survey findings and obtain more specific details. Secondly, a quantitative analysis of grades obtained from group projects, carried out by the students, was also performed. The use of these two analyses allowed for a more comprehensive and evidence-based view of the impact of PBL on students' acquisition of statistical knowledge.

Data Analysis

To achieve the objectives of this research, a data analysis was conducted, taking into account its specific nature.

Regarding the qualitative analysis, the focus was on the data collected through surveys and supplementary interviews. During this process, thematic coding of the students' responses was performed to identify patterns and recurring themes related to their perceptions of the impact of PBL on applied statistics in health sciences. This approach facilitated a detailed and in-depth interpretation of the students' experiences and opinions, based on the methodology of content qualitative analysis (Alhussain et al., 2020).

On the other hand, the quantitative analysis centered on examining the grades obtained in group statistics projects to establish correlations between these grades and the students' perceptions and comments. This analysis involved the use of descriptive statistics to gain an overall view of academic performance associated with the use of PBL, following the methodology proposed by Jaiswal et al. (2021).

Finally, the integration of findings derived from both quantitative and qualitative analyses was carried out to achieve a comprehensive understanding of the impact of PBL on statistical education and its influence on academic performance. The integration of this data aimed to confirm, complement, or contrast the results obtained through different methods, thus providing a more complete and nuanced perspective on the research topic, following the guidelines established by Clark (2019).

Results

In this section, the survey and supplementary interview results are presented according to the SOs outlined in the study.

For SO1, a survey consisting of 18 open-ended questions was designed by a team of three professors and a healthcare professional. This survey was based on a study conducted by Pradanti and Muqtada in 2023 and addressed various aspects related to satisfaction and goal achievement, the development of statistical skills, the use of resources and tools, communication of results, teamwork, critical thinking, evaluation, challenges and difficulties, suggestions for improvement, as well as the influence on perception and academic progress. The main purpose of this survey was twofold. First, it aimed to collect valuable information that would significantly contribute to the improvement of future implementations of PBL in the field of applied statistics in health sciences. Second, it intended to understand students' perceptions of this teaching approach and evaluate the influence that this project has had on their learning process and the development of their statistical skills.

Subsequently, the results obtained are presented, approached from two perspectives: qualitative and quantitative. From a qualitative perspective, a detailed analysis was conducted of the responses collected through students' opinions from the open-ended questions in the survey (questions 1 - 18) with twenty-six students and in-depth interviews. This process allowed for the organization of information into four main categories, which emerged from both the collected data and the analysis conducted by the team. These categories are: 1) Development of skills and application of knowledge; 2) Communication and feedback; 3) Collaboration and teamwork; and 4) Overall experience and personal reflection, including representative examples for each category. On a quantitative level, a five-level rating technique was implemented to categorize each of the comments provided by the 26 students in relation to the 18 survey questions. This association of comments with their respective rating levels facilitates quantitative analysis, providing an overall view of the students' learning in the study with the PBL approach.

From the qualitative perspective, the analysis condenses student opinions from the open-ended questions in the survey (questions 1 - 18) with twenty-six students and in-depth interviews, classifying the responses into the corresponding categories. Below are the categories and some student responses.

Category 1) Development of skills and application of knowledge

In this category, we focus on the use of PBL for the development of critical skills. The trends indicate that a considerable number of students viewed the research and data analysis activities positively. This aspect encompasses not only data collection and management but also the ability to efficiently use search tools and relevant technology, suggesting that PBL has promoted a practical and systematic approach to statistics. For example:

> "Learning to research better, I was able to find more search tools as well as more sites to gather information." (Student 6)
> "I think it's something that still needs reinforcement, but I consider data collection and being organized in tables as a great achievement since I don't have much knowledge in Excel, which is the app commonly used for this." (Student 25)

Additionally, there are responses highlighting a significant improvement in creating and understanding graphs and tables, especially through the use of software like Excel. This demonstrates proficiency in data visualization, which is essential for interpreting and effectively presenting research findings. For example:

> "PBL really highlighted the importance of visual representation in statistics. Learning to create graphs not only made the data come to life but also allowed me to see the stories that those numbers tell. This skill is something I know I will use a lot in my future as a healthcare professional." (Student 8)
> "Mastering Excel through the project was eye-opening. The ability to organize and present data in tables is fundamental, and now I feel like I have a powerful tool at my disposal for future research and statistical analysis in my career." (Student 21)

Furthermore, some comments mentioned regarding interpretation and statistical analysis show that in some students, the project fostered a competence specific to statistics: the ability to handle statistical concepts for critically evaluating scientific literature. This aspect reflects a notable improvement in students' discernment when selecting reliable academic sources and their understanding of how data supports scientific conclusions. For example:

> "At first, reading and interpreting graphs was like deciphering a foreign language, but with the constant practice that PBL encouraged, I now feel like I can understand and communicate statistical findings with much more confidence." (Student 4)
> "The project took us beyond just using charts; it taught us to extract meaning from them. Learning to calculate the mean, median, and mode was like getting the keys to data, opening up a new level of critical analysis that I didn't know I could reach." (Student 17)

However, there is also a minority of students who did not identify the acquired skills or reported little change in their analytical abilities. This might indicate opportunities to optimize how PBL is communicated and integrated into the curriculum. For example:

> "PBL was a part of the course, but I didn't feel like it significantly transformed my learning process. While I recognize its value, I believe it would need to be more concretely integrated with our lab activities and class discussions to truly resonate with my learning process." (Student 3)

> "I confess that statistics has always been intimidating to me, and PBL adds a level of pressure that makes me anxious. Analyzing data under this methodology makes me feel out of my comfort zone, which can be stressful, although I understand it's an important skill to develop in my field." (Student 7)

Category 2) Communication and feedback

In this category, the majority of students mentioned receiving positive and constructive feedback, which is crucial for improving their ability to effectively communicate scientific findings. This feedback has become a valuable tool, assisting students in identifying their strengths and areas for improvement, both in written composition and oral presentations. For example:

> "The detailed review that the teacher provided for our project was key. It not only helped us organize our ideas but also taught me to structure information better, which is crucial for a coherent report." (Student 5)
> "The teacher's feedback was eye-opening; it allowed us to identify and work on our weaknesses. Without that guidance, many errors would have gone unnoticed." (Student 11)

Additionally, a segment of students recognized themselves in a developmental phase, expressing that they were improving and that the PBL process had helped them refine their communication skills. This suggests that PBL not only serves the transmission of technical knowledge but also fosters essential communication competencies. For example:

> "During the presentation, I felt like I could really connect with the audience. Using concrete examples helped me clarify complex points and ensure that the findings were understandable to everyone." (Student 10)
> "I feel confident in communication; presentations and reports are something I enjoy and handle with confidence, which I believe is reflected in the quality of my work." (Student 22)

There were also students who faced challenges, particularly in handling nervousness during public presentations. Practice and relaxation strategies recommended by the teachers have been essential in overcoming these obstacles, allowing students to present with more confidence. For example:

> "The standards for presentations were high, and despite following all the guidelines, I feel that we still haven't reached the expected level. It's an area where we definitely need to improve." (Student 16)
> "Public speaking is still a challenge for me. Although I'm working on it, I still feel that I need to overcome the nervousness barrier to communicate my ideas clearly." (Student 20)

On the other hand, some students mentioned specific difficulties in conveying information, highlighting the importance of personalized feedback to support individualized learning. Additionally, there was a minority that did not provide details about their communication process or did not face significant challenges, which may indicate variability in individual experiences or a possible reluctance to share difficulties. For example:

> "Personally, I didn't find significant obstacles in communicating our findings. I feel that our team did a good job conveying the information clearly and accurately." (Student 12)
> "Collective feedback was very beneficial, but I think we also need individualized feedback to address our areas of improvement more effectively." (Student 13)

Category 3) Collaboration and teamwork

In this category, the majority of students reflected on positive and collaborative experiences, highlighting the effectiveness of working together and sharing credit for team achievements. This positive perception emphasizes that collaboration not only enhances the quality of work but also distributes the workload more equitably. For example:

> "At the beginning, forming the team felt like rolling the dice; we were all new acquaintances and were unsure how to choose partners. However, we overcame the initial uncertainty and successfully completed the project." (Student 10)
> "Our start as a team was complicated; there was an imbalance in contribution. After an open conversation with the teammate in question and with the support of our teacher, we found a work rhythm where everyone could contribute equally." (Student 17)

However, some students reported mixed or varied experiences, suggesting that group dynamics and the team formation stage can significantly influence the collaboration experience. In some cases, individual differences and adapting to new teams presented initial challenges that eventually turned into valuable learning experiences.

> "Frankly, teamwork was not very good, mainly because we were just getting to know each other. Eventually, one person is left advancing the work, and the rest of the team, almost nothing." (Student 12)
> "Personally, I enjoyed the team experience. Sharing and expanding perspectives with others enriched our work and the learning process." (Student 26)

Furthermore, in this category, students also mentioned topics related to planning, communication, and collaborative work. Planning emerged as a fundamental pillar for effective teamwork. Students

recognized the importance of setting schedules and dividing tasks, which facilitated a more structured and organized progression of the project. For example:

> "We discovered that the key to team success was solid organization, setting a clear order, and having a person to lead the group." (Student 17)
> "I was fortunate to be part of a team where transparency and cooperation were the norm. This collaborative environment brought us closer with each project milestone." (Student 22)

Regarding effective communication, it was highlighted as an essential strategy for maintaining clear and constant collaboration. The use of various means of communication reflects adaptability and openness to the communication needs of each team member. For example:

> "From day one, we established a communication channel via WhatsApp. This was crucial for exchanging ideas and monitoring our progress constantly." (Student 4)
> "Everyone contributed, but it's inevitable to notice that sometimes the effort is not uniform; some teammates seemed to be taking the lead." (Student 25)

In terms of collaborative work and mutual support, they also identified these as crucial aspects of the process, where equity in task distribution and readiness to help each other contributed to the harmonious development of the project. For example:

> "We did all the work together; we used to meet in the afternoon at the library or the autonomous study room to collect data and gather information." (Student 19)
> "Companionship was the driving force that propelled our project forward, culminating in work we all feel proud of." (Student 24)

Within collaborative work, some students emphasized the value of collaboration as key elements for success and project efficiency. For example:

> "The need to work as a team was evident from the beginning. Sharing the workload not only made the process more manageable but also enriched the content of our report." (Student 8)
> "Throughout the project, I learned the immense value of collaboration. Assigning tasks based on individual strengths was not only efficient but also allowed each person to shine in their specialty." (Student 11)

Category 4) Overall experience and personal reflection

In this category, students expressed positive feelings both about the overall satisfaction with the program and specific achievements. This includes the joy of accomplishing set objectives, gaining

new knowledge, and seeing tangible and useful outcomes in their learning. This category encompasses both general satisfaction and specific satisfaction related to the achievement of results and acquired knowledge. For example:

> "Participating in the project has given me valuable insights into how health topics integrate into our field. I genuinely feel it has enriched my understanding of the health field." (Student 2)
> "It was an intense semester, focused on learning to analyze data and tables for health sciences research. I found it challenging, but incredibly useful in understanding how information is processed in our field." (Student 15)

Many students emphasized the importance of developing analytical and collaborative skills, as well as the value of understanding and applying the research process. These aspects are directly related to the gratification found in the learning process and the development of practical skills. For example:

> "Working as a team was an enriching experience. We learned not only to collaborate efficiently but also how to combine our skills to achieve a common goal, which was very rewarding." (Student 19)
> "Analyzing graphs and data related to health sciences was perhaps the most significant achievement for me. It gave me a real sense of contributing to the field with practical and relevant work." (Student 21)

Additionally, they identified challenges in information management and methodology, as well as suggestions for improving feedback and clarity of instructions. This may reflect the difficulties encountered in handling information properly and the need for more effective communication and clear guidelines. For example:

> "The process of conducting tests and collecting health data involved talking to relatives, friends, and neighbors. This interaction made me realize the importance of communication and community outreach in our field." (Student 22)
> "Handling project variables was perhaps the most complex challenge. I faced situations I had never considered before, which pushed me to think more critically and analytically." (Student 25)

Furthermore, there was a segment of students who recognized the value of the PBL experience in their academic and future professional development, viewing it as a solid foundation for future research and thesis projects. For example:

> "The most valuable aspect was learning to analyze and extract data from scientific texts. This practical and research-based approach has provided me with fundamental tools for my career." (Student 15)
> "This project has given us a research foundation that will surely be useful in the future. Now, when we are asked to conduct research in other subjects, we will have an initial advantage." (Student 25)

However, there were also students who did not provide specific information, did not identify challenges, or did not reflect on the program's influence on their academic and professional development. This suggests a variety of reasons, such as lack of interest, unmet expectations, or a disconnect between the learning experience and their career planning. For example:

> "Honestly, I haven't thought much about how this project affects my academic development. Maybe I need more time to appreciate its impact on my learning and professional development." (Student 12)
> "At this point, I don't feel that the project has had a positive impact on me. In fact, it has made me somewhat reluctant to research due to the workload. I prefer a more traditional approach to learning, where information is presented to us and then we study it." (Student 14)

On the other hand, we categorized the comments of each student in this study, adopting a five-level rating system. Each level corresponds to a specific score, with 0 indicating "Does not Value" and 4 indicating "Highly Values," as detailed below:

- *Does not Value* (Score 0): The student shows complete indifference or disinterest in the topic. Responses may be non-existent, vague, or irrelevant to the subject at hand.
- *Values Slightly* (Score 1): There is minimal or superficial appreciation of the topic by the student, with slight recognition of its value or importance but lacking depth or significant details.
- *Values Moderately* (Score 2): The student recognizes and values the topic with a basic understanding. Responses show some commitment and reflection, though they are not comprehensive or deep.
- *Values Noticeably* (Score 3): A good understanding and appreciation of the topic are reflected, with responses including details and specific examples, demonstrating well-developed commitment and reflection.
- *Highly Values* (Score 4): The student exhibits an excellent understanding and high appreciation of the topic, with detailed, deep, and articulated responses, showing exceptional commitment and reflection.

This rating system allows for the quantification of qualitative statements from students in surveys and interviews, facilitating a clear and structured evaluation of their perceptions and opinions. It

is worth mentioning that this adopted technique is based on well-established qualitative and quantitative assessment approaches in the field of educational research. Studies such as those by Keiper et al. (2021) and Mertens (2023) emphasize the relevance of mixed methods for gaining a deep understanding of students' perceptions. Table 3 records the mean score and standard deviation (SD) of the 26 students for each survey question.

Table 3. *Mean score and SD of the 26 students for the survey questions.*

Question	Mean score	SD
1	2.38	0.85
2	2.04	0.96
3	1.73	0.92
4	2.15	0.88
5	2.31	0.84
6	1.96	1.11
7	1.96	1.08
8	1.69	1.16
9	1.81	0.94
10	2.19	0.69
11	1.92	1.02
12	1.92	0.84
13	1.92	0.80
14	1.88	1.07
15	1.58	1.03
16	1.50	0.81
17	2.04	1.04
18	1.77	1.11

The table above displays a variety of student opinions, reflecting both positive aspects and areas for improvement. Higher mean scores in questions such as 1, 5, and 10 suggest that certain elements of ABP are well-regarded, possibly due to their effectiveness in improving understanding and practical skills in statistics. However, lower mean scores in questions like 3, 8, 9, 15, and 16 indicate less favorable aspects of ABP, which may point to deficiencies in the methodology or its implementation. The variability in responses, observed through the standard deviations, reveals consensus in certain areas (low SD in questions like 10 and 13) as well as a wide range of opinions in others (high SD in questions like 6, 7, 8, 14, and 18), highlighting the heterogeneity of students' experiences and perceptions. This set of results underscores the need for ongoing evaluation and adaptation of ABP, considering both positively valued elements and those requiring improvements, to effectively meet the varied needs and expectations of students in their statistics learning.

Using this technique, the comments of each student were analyzed and rated on a scale from 0 to 4. This scale allowed for the assignment of a specific mean score to each student. Table 4 presents

the 26 participating students based on their mean scores obtained from their responses to the 18 survey questions. Upon careful analysis of this table, it can be observed that the mean scores have grouped students into five distinct categories. Students are classified as "Highly Values" when their mean score reaches the maximum value of 4. Those who scored between 3 and 4 fall into the category of "Values Noticeably." On the other hand, students with mean scores between 2 and 3 are considered "Values Moderately," while those with mean scores between 1 and 2 are in the category of "Values Slightly." Finally, the category of "Does not Value" is for students whose mean score does not exceed the value of 1.

Table 4. Distribution of students by mean score.

Rating level	Mean score (x)	Number of students
Highly values	$x = 4$	0
Values noticeably	$3 \leq x < 4$	1
Values moderately	$2 \leq x < 3$	8
Vaules slightly	$1 \leq x < 2$	16
Does not value	$0 \leq x < 1$	1
	Total	26

According to the table, there is an interesting distribution of student mean score in the survey. It is noteworthy that no student reached the highest level of assessment, "Highly Values," implying that no participant achieved a perfect mean score of 4. On the other hand, only one student fell into the category of "Values Noticeably," with a mean score between 3 and 4, suggesting it was an isolated case of relatively high performance. Most students concentrated in the middle and lower levels of assessment. Specifically, eight students obtained a mean score that placed them in the "Values Moderately" category, meaning between 2 and 3. However, the most populated category was "Values Slightly," with 16 students, indicating that the majority of participants had mean score between 1 and 2. This suggests a generally low level of response on the survey. Finally, only one student was in the lowest category, "Does not Value," with a mean score below 1, indicating that almost everyone surpassed the lowest mean score. In summary, this distribution reflects that while most students did not achieve high levels of mean score on the survey, they also did not concentrate at the lower end of the scale, with the majority scoring in the intermediate to lower range.

During the interview with the teacher, she emphasized that throughout her years of experience teaching mathematics and statistics, she has always believed her knowledge could enhance the learning of higher education students. However, since she began implementing PBL in her course, she realized that her disciplinary and pedagogical knowledge was not sufficient to integrate relevant aspects from other disciplines, which led her to recognize the need for further training. To address this need, the research team provided her with information about the importance of consulting the literature, challenging her previous notion that educational guidelines come solely from the education ministry or the curriculum, and that knowledge is acquired exclusively through books.

By exploring the literature, she discovered more concrete and up-to-date strategies and actions that she could apply to her course. During the implementation of PBL, when faced with the task of reviewing each part of the students' work, she was forced to conduct thorough research and

carefully study every aspect of the projects presented. This involved assessing the feasibility of applying certain mathematical and statistical concepts in the specific context of kinesiology chosen by the students. This experience represented a deep dive into the application of mathematics, thus demonstrating that this discipline serves as a tool in other areas of study. Although she claimed to have known this premise previously, it was confirmed through the implementation of PBL in her course. She felt that this approach not only allowed her students to apply statistical knowledge and model professional practice situations but also motivated her to deepen her mastery of these concepts and to understand the kinesiology fields of interest to her students, as well as how to link them with mathematics and statistics.

Regarding SO2, we present the grades obtained for the group project carried out during the first semester of 2023. During this period, students were divided into teams of five members each, with the aim of conducting a statistical study. This study focused on proposing solutions to specific problems in their respective professional areas. A notable example was the analysis of heart rate in children with obesity. This project was structured in several phases, starting with the preparation of a detailed and rigorous report. This report was required to include an introduction, theoretical framework, methodology, formulation and analysis of results, followed by discussions and relevant conclusions. This structure ensured comprehensive coverage of all stages of the project.

Continuing with the report preparation process, the supervision of the professor played a crucial role. She meticulously supervised the progress of each group, using evaluation rubrics previously defined by the research and teaching team. This thorough monitoring process paid special attention to key sections such as the introduction, theoretical framework, methodology, conclusion, and recommendations. Once the written report stage was completed, students moved on to the oral presentation. In this phase, a specific evaluation rubric was applied to assess their performance.

It is important to note that, beyond the report progress monitoring, students received individual grades for each monitoring phase, as well as for the oral presentation. This was done during interactions with the professor, who asked each student questions related to the work they had done. These grades were assigned on a scale from 1 to 7, following the Chilean assessment system, where 4.0 represents the minimum passing grade, and 7.0 is the maximum.

To provide a broader and more detailed view of the evaluation process, Table 5 presents the grades achieved by students in each stage of the project. These data are presented alongside the respective assessment levels determined based on the survey comments obtained. This table not only reflects numerical results but also provides a qualitative perspective on student learning and performance.

Table 5. *Grade of progress monitoring and oral presentation.*

Student	Progress monitoring 1	Progress monitoring 2	Progress monitoring 3	Oral presentation and final PBL report	Survey mean score	Rating level
1	3.2	3.2	4.5	5.4	1.50	Values Slightly
2	5.5	3.5	2.1	4.3	1.78	Values Slightly
3	5.3	3.0	3.2	4.6	1.72	Values Slightly
4	3.7	4.3	4.9	5.5	1.78	Values Slightly
5	6.7	5.9	5.5	6.5	3.06	Values Noticeably

6	4.0	3.8	4.2	5.5	1.89	Values Slightly
7	4.4	4.3	3.2	3.2	0.67	Does not Value
8	3.6	3.6	4.1	4.3	1.94	Values Slightly
9	4.4	5.7	3.5	4.6	1.72	Values Slightly
10	3.1	3.9	4.3	5.8	1.83	Values Slightly
11	4.1	3.5	4.3	4.8	1.89	Values Slightly
12	3.7	4.3	5.1	5.4	1.72	Values Slightly
13	4.0	3.3	3.5	4.5	1.39	Values Slightly
14	5.6	4.7	5.1	5.7	1.39	Values Slightly
15	4.5	4.1	5.3	4.6	2.56	Values Moderately
16	4.4	5.2	4.3	4.8	2.06	Values Moderately
17	4.4	4.3	4.6	4.8	2.39	Values Moderately
18	5.2	4.5	3.9	4.8	1.83	Values Slightly
19	3.7	5.2	4.1	3.8	1.67	Values Slightly
20	4.5	3.4	4.1	4.5	1.94	Values Slightly
21	4.9	5.4	5.1	5.1	2.06	Values Moderately
22	4.6	4.7	4.6	4.5	2.33	Values Moderately
23	4.9	4.5	4.5	5.4	2.17	Values Moderately
24	5.5	5.1	4.1	5.4	2.72	Values Moderately
25	4.5	4.3	4.4	4.1	2.28	Values Moderately
26	3.5	4.2	3.3	4.4	1.94	Values Slightly

According to the table data, it is evident that students who significantly value the project, as reflected in their survey mean scores and rating level, tend to achieve higher grades in all stages of the project. An example of this is Student 5, who places high value on the project and has consistently demonstrated outstanding performance in all progress monitoring stages and the oral presentation. On the other hand, those who show lower valuation or do not attach importance to the project tend to receive lower grades. Finally, this grade distribution suggests the relevance of valuation and commitment to the project in academic performance.

In order to determine if there is a statistically significant relationship between the grads obtained in the project and the perceptions expressed by the students, a bivariate correlation analysis was conducted. The results of this analysis are presented in Table 6.

Table 6. *Bivariate correlation result.*

Correlations		Oral presentation and final PBL report	Survey mean score
Oral presentation and final PBL report	Pearson correlation	1	0.435*
	Sig. (bilateral *p-value*)		0.026

	N	26	26
Survey mean score	Pearson correlation	0.435*	1
	Sig. (bilateral *p-value*)	0.026	
	N	26	26

* The correlation is significant with bilateral *p-value* = 0.05.

According to the data from the analysis, there is a moderate and statistically significant correlation (bilateral *p*-value = 0.435) between the grade obtained for the oral presentation and the project report and the score from the survey about perceptions of the impact of PBL from a statistical approach. This correlation in the educational context indicates that students who received higher grades in their oral presentation and report tend to have a more positive valuation of the impact of PBL, as reflected in the survey score, as illustrated in Figure 6.

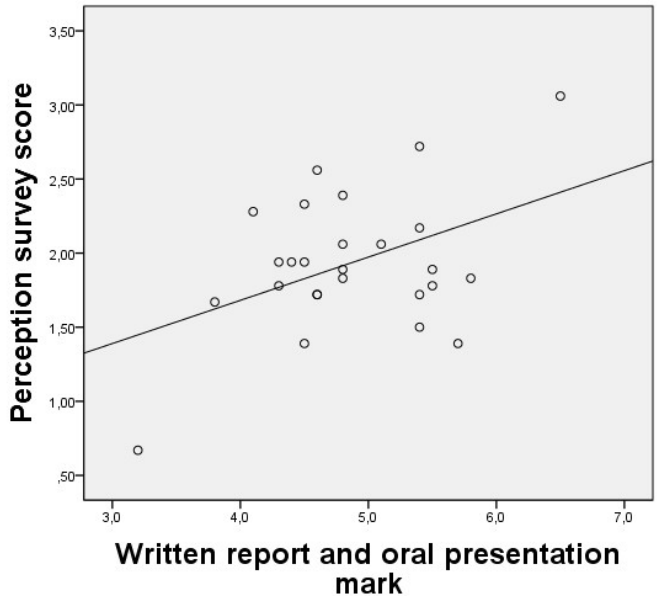

Figure 6. Relationship between score obtained from the project and perception survey.

However, since the correlation is moderate, this relationship is not strong or direct. This means that there are other factors that could also be influencing students' perceptions of PBL, such as personal interest in the topic, group dynamics during the project, or teaching style, which might be contributing to how students value their experience with PBL.

The statistical significance (bilateral *p*-value = 0.026) confirms that this correlation is unlikely to be random. This implies that in this educational context, the way students perceive and value their experience with ABP is somewhat related to their performance in the oral presentation. It could be interpreted that students who perform better in the oral presentation, perhaps due to a better understanding or greater commitment to PBL, tend to have a more favorable perception of this teaching methodology.

Additionally, we present an example of a project carried out by a group of students titled "Analysis of Heart Rate Variation in 19-Year-Old Individuals, Before and After Performing Specific Exercise Circuits, in Relation to Their Level of Physical Activity." This project corresponds to topic number 5 (see Table 2). It is important to note that the original work was conducted in Spanish, and we have translated procedural samples and Excel graphs from the report to facilitate its dissemination in the scientific community.

In the Introduction section, the students stated that their PBL project involves a study investigating how heart rate, assessed under various conditions, can indicate the state of cardiovascular health and overall physical fitness. This approach is supported by bibliographic references emphasizing the importance of cardiovascular monitoring. Furthermore, in this section, the students clearly defined their main objective and detailed the specific goals of their research.

In the Methodology section, the students provided a detailed description of their study's approach, specifying that it is quantitative and cross-sectional in nature. They also outlined the context and participants involved in the research. Additionally, they explained the techniques used for data collection (50-meter race, 1-minute squats, and 1-minute mountain climbers) and the procedures employed for analysis.

Figure 1 illustrates that the students conducted an experiment to recollect the heart rate responses of two different groups: 5 sedentary individuals and 5 athletic individuals. They measured the heart rate of each participant in both groups under three different conditions: before and after a 50-meter run, before and after a 1-minute squat exercise, and before and after a 1-minute mountain climbing exercise.

Heart rate in sedentary people

	Before 50m Race	After 50m Race	Before 1min Squats	After 1min Squats	Before 1min Mountain climber	After 1min Mountain climber
SedP1	76 bpm	162 bpm	76 bpm	150 bpm	76bpm	156 bpm
SedP2	84 bpm	174 bpm	84 bpm	156 bpm	84 bpm	158 bpm
SedP3	78 bpm	172 bpm	78 bpm	162 bpm	78 bpm	160 bpm
SedP4	72 bpm	152 bpm	72 bpm	144 bpm	72 bpm	162 bpm
SedP5	96 bpm	170 bpm	96 bpm	152 bpm	96 bpm	164 bpm

Heart rate of athletic people

	Before 50m Race	After 50m Race	Before 1min Squats	After 1min Squats	Before 1min Mountain climber	After 1min Mountain climber
AthP1	74 bpm	134 bpm	74 bpm	130 bpm	74 bpm	122 bpm
AthP2	70 bpm	140 bpm	70 bpm	135 bpm	70 bpm	138 bpm
AthP3	66 bpm	156 bpm	66 bpm	136 bpm	66 bpm	132 bpm
AthP4	58 bpm	108 bpm	58 bpm	124 bpm	58 bpm	114 bpm
AthP5	84 bpm	138 bpm	84 bpm	128 bpm	84 bpm	130 bpm

Figure 1. Work sample 1.

In Figure 2, the students conducted a comparison and analysis of the difference in the mean number heart rate of both groups, both before and after the 50-meter run. Similar analyses were also performed for the other two physical activities.

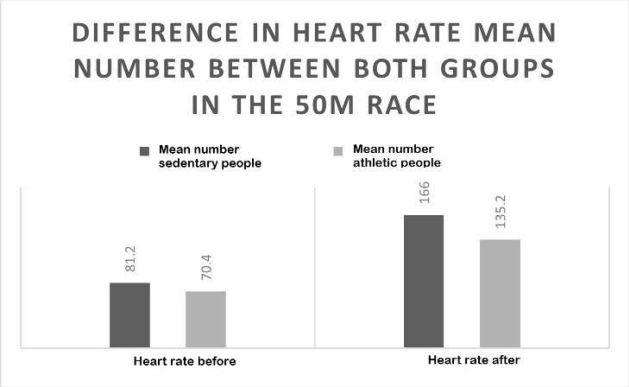

Figure 2. Work sample 2.

In Figures 3 and 4, the students selected one person from each group and conducted seven consecutive measurements, with one-minute intervals between each testing. This testing methodology was applied seven times in a row, first during the 50-meter race, followed by one minute of squats, and finally one minute of mountain climbers. Gathering these data allowed the students to develop a mathematical model based on their findings.

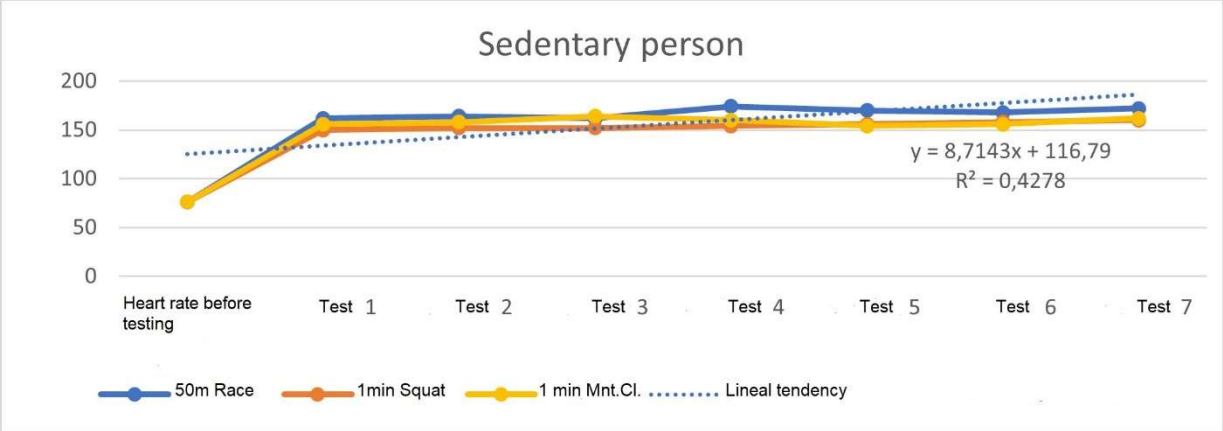

Figure 3. Work sample 3.

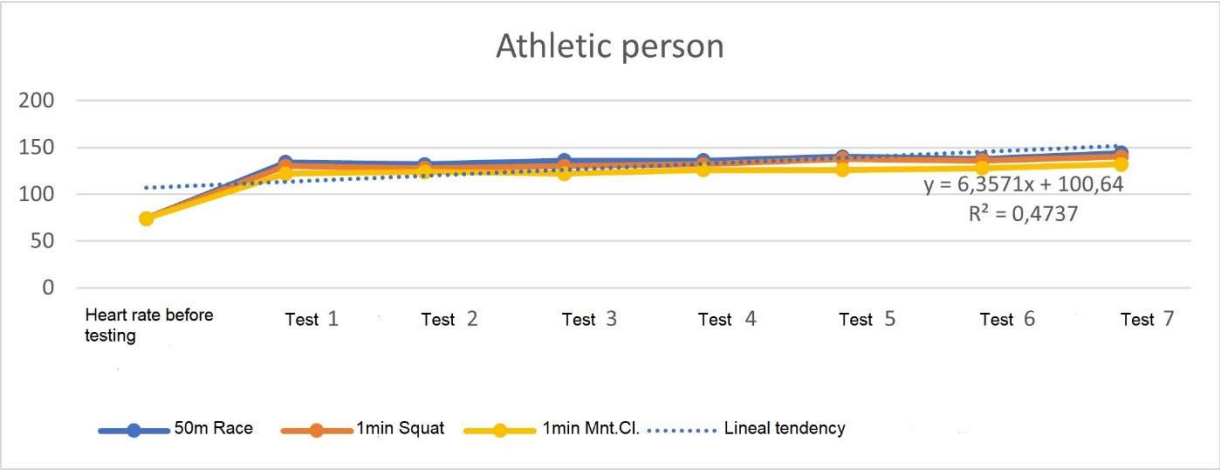

Figure 4. Work sample 4.

Then, in Figure 5, the students presented their formula for calculating the mean number heart rate and stated that this comparison demonstrates the variation in heart rate frequencies among individuals with different levels of physical fitness when they engage in the same physical activities.

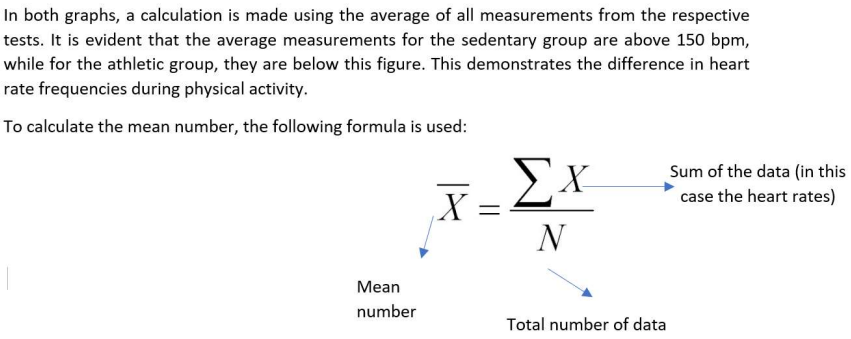

Figure 5. Work sample 5.

Finally, in their conclusions, the students highlighted a limitation of the study, which was the need to tailor the exercises to assess their impact on heart rate in both athletic and sedentary individuals. They confirmed that the research validates the hypothesis that the level of physical activity significantly influences heart rate, demonstrating notable differences among the studied groups. Additionally, they included the consulted bibliographic references.

DISCUSSION & CONCLUSIONS

Analyse the overall perspective of the development of the activity. Share the difficulties in the course of implementation. Analyse each variable taken into account in the methodology. Share the results of your work and relate them to the literature review. Review the objectives set up at the

beginning of the study. Make attempts to reflect on topics interesting to teachers, for example: how various aspects of the study may influence the results.

The implementation of PBL in applied statistics for health sciences in the Chilean university context has yielded significant results, as reflected in students' perceptions and performance. This study reveals that, overall, students have a positive view of PBL, although with variations in their rating level. When correlating students' valuation with their scores in progress monitoring and oral presentation, a clear trend emerges: those with a higher valuation tend to achieve better grades.

This trend aligns with existing literature highlighting the importance of student engagement and motivation in learning (Davidson et al., 2019; Pilot et al., 2023). The study by Pradanti and Muqtada (2023) suggests that when students recognize the relevance and applicability of what they are learning, their performance significantly improves. This is evident in the case of Student 5, whose high valuation of the project translated into outstanding grades.

The relationship between students' valuation of PBL and their academic performance (see Table 4) supports the theory emphasizing the relevance of active and team-based learning for the development of practical and analytical skills, as indicated by Huang et al. (2023). It is observed that students who exhibit higher appreciation for PBL tend to be more engaged in their learning process. This increased commitment is reflected in the advanced development of statistical competencies and their effective application in practical contexts.

On the other hand, the existence of students who slightly value PBL or do not value it at all, and who receive lower grades, indicates potential areas for improvement in the implementation of PBL. This finding suggests that some students may need more support to fully value the benefits of PBL, which is crucial for their engagement and performance. As highlighted by Elsamanoudy et al. (2021), it is essential to consider individual needs and differences in students' learning experiences.

The experience of the mathematics teacher highlights educational enrichment through PBL, emphasizing not only the importance of integrating various disciplines such as kinesiology into the teaching of statistics but also the need for continuous evolution in her field (Maass et al., 2019). This outcome has led to recommendations for the dissemination of PBL among teachers and students at all educational levels. Furthermore, it advocates for a pedagogy that values bidirectional communication and collaborative learning, allowing for the inversion of roles between teachers and students for mutual enrichment (Xie & Derakhshan, 2021). The implementation of PBL in statistics has shifted teaching towards practical applications, enhancing statistical understanding and contributing to patient quality of life, thereby demonstrating the relevance of statistics in professional contexts (Guo et al., 2020; Rajula et al., 2020).

This study on PBL in applied statistics for health sciences among Chilean university students highlights significant implications for statistics teaching in the field of health.

Pedagogical Implications: PBL has been shown to improve analytical and practical skills in statistics. Therefore, educational programs must integrate theory with applied practice, as suggested by Dawadi et al. (2021) and Mertens (2023). Constructive feedback and the development of communication skills are crucial to prepare students for professional communication (Ridlo, 2020). Additionally, effective collaboration, vital for success in group projects, should be encouraged in curricula (Hussein, 2021). Revelle et al. (2020) emphasize the importance of spaces for personal reflection and the analysis of learning experiences.

Implications for Academic Assessment: The correlation between the appreciation of PBL and grades indicates the need to adopt assessment methods that go beyond traditional approaches, recognizing active participation and the development of practical skills (Birdman et al., 2022).

Although the findings suggest that PBL enhances analytical and practical skills and fosters motivation (Dawadi et al., 2021; Mertens, 2023), one of the main limitations is the specific focus on the Chilean context. While it provides deep insights into students' perceptions and adaptation to this pedagogical approach in a particular setting (Huang et al., 2023), it may not fully capture the varied experiences and perceptions in different educational environments within health sciences. This highlights the need for comparative studies in other geographical and cultural contexts to enrich the global understanding of PBL in statistics.

Furthermore, future research should delve into the nuances of how PBL in statistics is received and implemented across different cultural contexts and educational systems. Investigating the variations and parallels in the implementation of PBL and its perception among various countries and academic disciplines may provide a richer and more nuanced understanding of its effectiveness and adaptability to diverse learning environments (Elsamanoudy et al., 2021; Pilot et al., 2023). Additionally, conducting longitudinal studies that track students over significant periods (from lower secondary education to higher education) emerges as a particularly valuable recommendation. Such research is poised to shed light on the sustained effects of PBL on students' academic and professional growth, offering insights into the lasting influence of PBL on career paths and academic advancement, especially within the realm of health sciences (Davidson et al., 2019). Adopting a comprehensive longitudinal approach, as suggested, would significantly enhance our understanding of the long-term impact of PBL, from secondary education to tertiary levels, thereby providing a more holistic view of its benefits and challenges across the educational spectrum.

In conclusion, this study illuminates the implementation of PBL within the Chilean educational system, providing valuable insights. However, for a more comprehensive and globally informed perspective on this educational approach, future research should expand its focus both geographically and temporally. To maximize the potential of PBL, it is essential for educators and curriculum designers to effectively communicate its goals and advantages (Ngereja et al., 2020), incorporate hands-on activities like laboratory work to enhance its impact (Domenici, 2022), and

ensure ongoing support for students who may find PBL challenging (Boss & Krauss, 2022). Crucially, efforts should be made to facilitate students' exploration of learning opportunities that extend beyond the traditional curriculum.

Therefore, it becomes imperative to not only spread knowledge about PBL among secondary and higher education teachers and students but also to engage policymakers who may not be familiar with educational methodologies. By broadening the awareness and understanding of PBL among these key stakeholders, the groundwork can be laid for more informed decisions that support the integration of PBL into educational systems, thereby fostering an environment where learners can thrive both within and beyond the confines of their school curriculum (Authors, XXXX).

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