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Challenges Faced by Students in Adopting PBL in Environments of High Social Inequality: An Instructors' Perspective From a Latin American Case*

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Engineering education has widely adopted project-based learning (PBL) because of its effectiveness in developing students' capabilities to face society's current, complex challenges. However, both students and professors are challenged while adopting PBL. These challenges increase when students' technical and social backgrounds are highly heterogeneous within a course, as seen in many Latin American engineering faculties due to economic and social inequalities. Using the case of an engineering faculty from Latin America, in this study, we examine specific barriers caused by students' social heterogeneity and how professors handle these barriers in fresher courses. Specifically, we propose that heterogeneity generates asymmetries in students' technical backgrounds, social competence, and engagement, which professors address using scaffolding, teamwork, and identification mechanisms. Theoretically, this study partly reveals the particular dynamics that engineering professors face in Latin American countries. Alternatively, from a practical standpoint, we provide engineering professors with insights into implementing PBL in these environments.

Keywords: engineering education; project-based learning; barriers; heterogeneity

1. Introduction

Engineers require a broad set of technical and interpersonal skills to tackle complex, open, and multidimensional problems. Therefore, engineering faculties face the challenge of developing these skills in their students. Project-based learning (PBL) has been a widely adopted methodology for achieving this aim because it allows students to construct knowledge and develop skills by performing meaningful projects and developing real-world products [1, 2]. However, following various studies, PBL implementation is seen as challenging for professors, as it requires substantial changes to teaching [3] and assessment. On the one hand, in PBL environments, professors need to transfer their roles from lecturers to facilitators [4, 5]. On the other hand, defining assessment methods is complex because professors need to examine both the development of students' skills and actual learning outcomes in one course [6].

However, most studies have assessed the phenomenon in developed countries [7], and how these challenges could change in developing countries is not well-known, particularly in Latin America. Although many countries in Latin America have progressed in education, socioeconomic inequalities still trigger high asymmetries within the educational system. Notably, in Chile, the socioeconomic level of families is a fundamental indicator that explains university fresher students' performance [8]. For instance, only 13% of students with high scores on the university admission test are from public schools, 30% are from charter or semi-private schools, and 56% are from private schools [9]. These asymmetries imply that engineering faculties receive students with different capabilities, working habits, and paradigms about their classmates, which can be an additional challenge for professors in implementing PBL processes.

Given this gap, this study's aim is to highlight this phenomenon by exploring the staff of a Chilean engineering faculty in delivering PBL to identify, according to professors' perspectives, the main barriers triggered by fresher students' social heterogeneity and how professors tackle these barriers during PBL implementation. We inductively analyzed information from 25 professors who taught initial engineering courses using the PBL methodology. In this process, we found that professors consider that heterogeneity triggers students' knowledge, social, and engagement asymmetries, and to tackle these asymmetries professors use scaffolding, teamwork, and identification mechanisms.

This study's findings contribute by acknowledging the effect of heterogeneous educational systems on fresher engineering students, recognizing how these asymmetries may impede PBL implementation, and identifying how professors may

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handle these barriers. Neglecting this singular characteristic of these contexts could induce unsuccessful performance, demotivating professors from persevering with this methodology. Finally, some of the findings may apply to other engineering faculties, such as the Chilean context.

The article is structured as follows: In Section 2, we review the literature about the challenges to PBL implementation and the heterogeneous educational system in Chile. Then, we discuss the methods and data in Section 3 and the results in Section 4. Finally, in Section 5, we discuss the study's findings.

2. Literature Review

Engineers must be equipped to identify and solve current and future challenges. To achieve this aim, engineering faculties have adopted PBL as a fundamental method for developing engineering skills [10, 11]. This methodology increases student motivation and, consequently, academic performance [4]. Simultaneously, PBL helps develop transferable skills, such as teamwork, communication, problem-solving, and self-learning [4].

However, implementing these new methodologies is not easy, and the transition to PBL brings challenges [11, 12]. These challenges can be organized into two broad categories: for the staff of professors who implement courses in PBL mode [13], and for engineering students, especially in the early years, when participating in a radically new learning environment [14].

From the professors' perspective, the implementation of PBL requires them to form a body of theoretical knowledge and skills [15, 16]. Among the skills that must be developed, the following stand out: (a) to promote the professor's role as a mediator of learning [4, 7, 12, 14], (b) to combine methods to develop personal and interpersonal skills [7, 17], and (c) to combine traditional and new assessment methods that measure the development of transferable skills and learning outcomes in a course [6, 18, 19]. Additionally, PBL may also require that professors dedicate a more significant amount of time to designing the courses, especially when they must define projects appropriate to the characteristics and experience of the students, the type of project, and technological availability.

From the students' perspective, they face two main challenges that represent an additional difficulty in the learning process in a PBL context. The first is the degree of autonomy and self-learning skills to identify problems and build the necessary knowledge to arrive at practical solutions [14, 20, 21]. In this sense, motivation and self-reflection capacity are required for PBL to be effective [22, 23]. Second, students do not develop work skills spontaneously, and not all students have positive prior experiences. Consequently, attitudes may not be the most favorable about the adoption of this new methodology. For instance, for the development of PBL courses, students must learn how to organize work, manage conflicts, challenge free-loaders, and other aspects [24, 25].

These challenges could increase or decrease depending on the context in which PBL is applied. For example, studies have examined how collaboration and teamwork could be more complex in courses with high cultural heterogeneity due to the differences in work habits and paradigms that shape their way of behaving and thinking [24]. Thus, students' different cultural backgrounds can affect their participation, motivation, satisfaction, and performance during collaborative learning activities [26]. Other contextual characteristics could also affect the effective implementation of PBL, such as the high inequality between educational opportunities in developing countries such as those in Latin America.

The literature has shown high levels of inequality in Latin American education [27, 28] and the permanence of school segregation patterns between wealthy and poor groups [29]. Various Latin American countries exhibit a high association between parental resources and academic achievement [30]. For instance, in Chile, "students' socioeconomic origin determines access to higher education and its subsequent academic and economic success" [31]. According to the OECD (2014), 37% of 15-year-old Chilean children attend public (state) schools, 48% attend semi-private schools, and 14% attend private schools. This segregation triggers silos in which students merely share their learning processes with socioeconomically similar classmates; that is, the context of the Chilean educational system and the aspect of learners' preconditions are determined by their socioeconomic position in society.

Nevertheless, private institutions and the government have sought to reduce these asymmetries by offering bursaries for poorer students, heterogeneous ways of selecting students for entering universities, and special access for less favored students [32]. In turn, universities are a place where students can share their formative years for the first time with students from diverse social backgrounds. This difference implies, for instance, that an engineering degree in Chile lasts six years as a mechanism to rectify and ensure quality and consistency among Chilean engineering graduates [31].

Therefore, in this study, we examine how students' asymmetries in their educational backgrounds affect the implementation of PBL and the strategies that professors use to manage this heterogeneity.

3. Methods

3.1 Research Settings

The Engineering Faculty of Universidad Católica del Norte was founded in 1960. The faculty is located in the north of Chile and has over 3,000 students. The faculty offers diverse degree programs in industrial, civil, chemical, mining, and metallurgical engineering. The faculty receives around 500 new students yearly from various economic sectors [6]. There is a high correlation between the type of school and family socioeconomic status in Chile. Most students from low-income families attend public schools, whereas students from high-income families attend private schools [29]. Therefore, the type of school can be considered a valid proxy for assessing the social diversity of engineering students. In the UCN, approximately 20% of the students are from private schools, 40% come from semi-private schools, and 40% are from public schools. The average retention rate in the second year was 65%, and in the third year it was 54% (see Appendix A). Thus, the faculty students' social configuration offers a sample of students with quite heterogeneous technical and social competencies.

In 2014, the Engineering Faculty redesigned its engineering programs using the Conceive Design Implement Operate (CDIO) principles [33]. Due to this redesign process, every discipline was assigned six or seven courses under the project-based learning methodology. This redesign offers a broad sample of courses to examine professors' perceptions of using the PBL methodology in engineering education.

Therefore, Universidad Católica del Norte (UCN) offers a sample where researchers can capture patterns of the effect of students' heterogeneity on PBL implementation in engineering education.

3.2 Sample Characteristics

Table 1 shows the professors' demographic characteristics that were examined. The professors taught diverse programs, including construction, civil, industrial, mining, metallurgy, chemical, and system engineering. The course lecturers comprised, on average, 29% women and 71% men. The professors' average age (ave. age) and standard deviation (des. age) were quite similar for females and males (43.2–45.2; 11.9–13.1). The professors' educational degrees were PhD, master's (MS), and bachelor's (Bch) degrees. Most of the professors have experience and have been trained in PBL methodology.

Table 1. Demographic characteristics of the sample

Lecturers Courses 1 to 4					
Female			**Male**		
N°	Ave. age	Des	N°	Ave. age	Des
12	42.8	11.9	18	43.2	13.10
Academic degree					
Bch	MS	PhD	Bch	MS	PhD
6	3	3	6	6	6
PBL training					
Yes	No		Yes	No	
6	6		12	6	
Experience in PBL courses					
Yes	No		Yes	No	
6	6		11	7	

3.3 Sample Analysis

This study is based on an inductive approach that distills theoretical propositions from data analysis [34]. Hence, the researchers have 49 videos where engineering professors who have applied PBL explained how they organized the courses, the problems they addressed, the students' characteristics, the strategies adopted, and the results achieved.

Initially, the researchers used the course degree and the course characteristics as the inclusion criteria. The research team included courses from the initial four semesters of the diverse engineering programs since the heterogeneity of students' skills is more pronounced. Additionally, we included courses that met the PBL design criteria established in the UCN curriculum design. Thus, the team obtained 30 cases.

For data analysis, we used the general inductive approach [35]. Similar to previous studies [36], data coding was done to answer both sets of research questions – what the barriers are and how professors handle them – through an inductive approach. The variables were coded inductively and iteratively using Atlas.ti [37].

The analysis of the individual cases focused on an iterative review of the professors' reports. The information was coded in an inductive and iterative manner by pairs of authors. The codes were generated freely, which means that there was no preconceived definition for them.

First, the authors listened to the cases and assigned preliminary conceptual codes to the professors' quotes [38]. Then, the data were summarized by aggregating codes that described similar features and facts. Then, as patterns and conceptual codes emerged, the authors returned to previously coded articles and cross-checked the relevance of new themes [34]. Next, the research team collapsed the codes recursively into themes. The research team cross-checked the coding results and revisited the quotes for re-coding. In the last cross-check process, the inter-rater reliability was 81%. Finally, the conceptual patterns of the researchers were mixed, eliminating redundancies and overlapping.

Table 2. General Categories

Code	Name	Description
ASYM	Asymmetries	Professors' perceptions of the differences observed between students of different socioeconomic levels
STRAT	Strategies	General actions professors take to level entry students' knowledge and skills
MECH	Mechanisms	Specific practices professors use to reduce student asymmetries

As a result of this process, three general categories were identified: asymmetries, strategies, and mechanisms, as Table 2 shows.

In the first iteration, the researchers focused on professors' questions about the barriers faced by first-year engineering students in courses under PBL. As a result of this analysis, specific students' asymmetries were founded. The next step was to review those citations that refer to the strategies that professors adopt to mitigate each of the asymmetries. Finally, the researchers focused on quotes about the specific instruments that teachers use to implement these strategies.

Regarding asymmetries, the research team identified three sub-themes that affect students' involvement in PBL engineering courses during the first years: knowledge, social, and engagement asymmetries. Knowledge asymmetries (ASYM-KNOW) describe the differences in initial knowledge between students. Social asymmetries (ASYM-SSKILLS) represent differences in students' social skills. Finally, engagement asymmetries (ASYM-KNOW) describe the differences in students' commitment to their academic training. Table 3 shows the types of students' asymmetries.

Concerning strategies, professors take diverse actions to help students deal with the asymmetries described above. The research team identified three sub-themes that describe these actions: scaffolding, teamwork, and identity. First, professors design the learning process using tools that guide students, both in the initial leveling process and the project's development. These data were coded as Scaffolding (STRAT-SCAFF) and favored students' transition with more significant knowledge gaps. Second, to promote the development of social skills, professors organize heterogeneous project teams, comprised of high- and low-income students. In this way, professors intend that the most disadvantaged students will develop communication skills and teamwork through social interaction. The quotations in this group were coded as Teamwork (STRAT-TW). Finally, to promote higher student engagement and commitment to the learning process, professors propose actions that seek identification with the selected engineering program and future professional practice (STRAT-IDENT). Table 4 shows these strategies.

Finally, the researchers identified specific mechanisms (practices) that professors use to achieve the objective of each of the strategies. The mechanisms associated with the scaffolding strategy are learning resources (MECH-LEARN), basic knowledge capsules (MECH-CAPS), and deliverables and templates (MECH-DELIV). The mechanisms associated with the teamwork strategy are complementary skills (MECH-COMPSKILL), work agreement (MECH-AGREE), feedback (MECH-FEED), and co-evolution (MECH-COEV). Finally, the mechanisms associated with the identity strategy are authentic and local projects (MECH-PROJ), practitioner talks (MECH-PROJ), and teacher assistants (MECH-ASSIST). Table 5 describes each one of these mechanisms.

Notably, as a final result, this study's aim is not to propose a grounded theory, but to help the reader

Table 3. Codification of Asymmetries

Code	Name	Description
ASYM-KNOW	Knowledge	Differences in knowledge levels about math and science
ASYM-SSKILL	Social Skills	Differences in students' communication skills
ASYM-ENG	Engagement	Differences in the degree of engagement with the learning process and resilience in the face of failure

Table 4. Codification of Strategies

Code	Name	Description
STRAT-SCAFF	Scaffolding	Specific actions taken by professors to diminish knowledge asymmetries of the students
STRAT-TW	Teamworking	Specific actions taken by the professors with the purpose of helping students work together despite their social fears
STRAT-IDENT	Identity Mechanisms	Actions aimed at reinforcing identification with the selected engineering program and future professional practice

Table 5. Codification of Mechanisms

Code	Name	Description
MECH-LEARN	Learning resources	Tools to facilitate students' learning, for instance, literacy lessons, protocols, exercises
MECH-CAPS	Basic knowledge capsules	Concentrated and self-contained classes addressing a fundamental concept to develop the project
MECH-DELIV	Deliverables and templates	Technical specifications of the results that students must present in the different stages of the project
MECH-COMPSKILL	Complementary skills	The development of tasks that require the contribution of different capacities of the students
MECH-AGREE	Work agreement	Contract signed by the students where the roles, tasks, work sessions, and control mechanism of the team and its members are established
MECH-FEED	Feedback	Information given to students about the attainment of learning goals related to teamwork performance
MECH-COEV	Co-evaluation	Evaluation between pairs of students based on a previously defined instrument
MECH-PROJ	Authentic and local projects	Proposals of problems and, consequently, projects that make sense beyond the academy and framed in a territorial context
MECH-PRACT	Practitioner talks	Meetings, seminars or talks by engineers from the industrial sector with extensive experience in projects
MECH-ASSIST	Teacher assistants	Input of teacher assistants to provide feedback and guide the development of projects

understand the barriers faced by engineering professors who apply PBL in engineering courses with high levels of social inequality.

4. Results

Table 6 summarizes the theoretical model, which contains three categories: asymmetries, strategies, and mechanisms.

In the following paragraphs, we elaborate on each asymmetry (barrier) and the strategies and specific mechanisms that professors use to help students deal with them.

4.1 Students' Technical Asymmetries

The professors observed various effects from students' social heterogeneity. First, the more apparent observation concerns the asymmetries in students' previous knowledge. In PBL contexts, students are expected to be the center of learning [3], which requires students to develop self-learning skills. According to professors' perceptions, progressing self-learning skills becomes tremendously challenging for those lacking basic scientific or mathematical knowledge, because before acquiring the information that the project requires to be solved, they need to fill their basic knowledge gaps. In turn, professors argue that they need to level students' capabilities before working on their course projects or problems. This leveling period limits the dedication time to work on the project, thereby reducing the project's scope and expected results. For instance, professors contended:

> "Some students are always late in the project task. They argue that they need first to study the basic concepts, which makes them run out of time to work on the project task. They are struggling in the first years." (ASYM-KNOW)

> "I have to go very slow with some of the students, whereas others get bored because they count with a broader base of knowledge (ASYM-KNOW). Thus, I must use diverse strategies to keep the project pace and the student engagement." (STRAT)

> "We normally take more than one month leveling the student's capabilities, and after this period, we just start to work on the project." (ASYM-KNOW)

Table 6. Theoretical Model

	ASYMMETRIES	*STRATEGIES*	*MECHANISMS*
Social and Economic Heterogeneity	***Knowledge***	***Scaffolding***	***Learning resources***
			Basic knowledge capsules
			Deliverables and templates
	Social skills	***Teamwork***	***Complementary Skills***
			Work agreement
			Feedback
			Co-evaluation
	Engagement	***Identity***	***Authentic and local projects***
			Practitioner talks
			Teacher assistants

> "Changing to PBL from traditional methods is already not an easy task, but the difference among students makes this effort more challenging. You must go very slow and try to be an octopus to solve the diverse needs." (ASYM-KNOW)

Professors argue that they have to help all students access the project regardless of the students' previous knowledge. Specifically, they mentioned that prior learning experiences should not be a barrier to doing the project and make students all progress toward course learning goals. Thus, they use diverse mechanisms to level students' knowledge background asymmetries and make this process more efficient in the first year of engineering. We inductively coded and aggregated these strategies as "scaffolding." The PBL literature has described scaffolding as the "help that moves students from what they can do now to what they will be able to do later" [39]. Scaffolds are like the training wheels on a bicycle and are introduced when students need support and, in many cases, are removed when no longer necessary. Specifically, the professors suggested:

(1) To make the learning resources readily available to facilitate initial students' knowledge leveling. For instance, a chemistry professor stated that "If I introduce some complicated scientific reading at the start of the project, some students will struggle with the task, so I start with a short initial literacy lesson. In turn, I make sure everybody can understand what they are about to read. Moreover, I make them work in pairs to check if everybody understands before they start to work on the project." (MECH-LEARN) Another professor argues that "I use protocols to make questions about basic knowledge where students have to work on pairs. This pair discussion helps them share their gaps and knowledge, thereby facilitating learning from their peers. Then, I promote a collective discussion that helps students to achieve a whole group consensus about basic things they must know before starting to work on the specific task of the project." (MECH-LEARN)

(2) To deliver basic knowledge capsules for easy and continual access to the high-school basic concept. For example, a professor argued, "When the semester began, I wrote a parabolic function on the board, and while some students quickly identified it and were able to graph it, other students began to replace point by point in the function to graph the function (ASYM-KNOW). Therefore, I recorded short videos explaining basic concepts such as 'functions' to diminish initial knowledge gaps among team members. So, students can access those videos before class. These capsules help students who do not handle basic knowledge to catch up with their team members and work better in the project tasks." (MECH-CAPS)

(3) To generate deliverables and templates that facilitate the common understanding of the project's expected tasks and evidence the students' knowledge gap. For instance, a professor from an introductory course in civil engineering asked students to design a fluvial vehicle. The deliverable stated that students must calculate the maximum load capacity of a floating vehicle. Students needed to know how to operate the buoyant force to achieve this aim. Detailed templates were provided that described what was expected as assignment results. (MECH-DELIV)

4.2 Students' Social Behavior Asymmetries

Additionally, following the professors' opinions, the students' technical background asymmetries also cause differences in students' behaviors.

Under PBL, students must express their ideas. Nevertheless, expressing their ideas can entail a personal risk when students feel threatened or embarrassed by their lack of knowledge or abilities. If they have this risk perception, they will likely feel intimidated about communicating their thoughts or questions. According to the professors' perceptions, this feeling is more prevalent among some students from low-income conditions.

For instance, professors have the perception that students who show a lower level of knowledge or a lower development of communication skills seem to be more insecure about their abilities, assuming a more passive role in which they perform the tasks assigned to them, whereas other students seem to have a more positive perception of their abilities, they show greater confidence when defending their ideas. Here, some visible behavioral clues support the professors' perceptions:

> "Often, some students have told me that they do not show up during project's presentation day because they do not trust what they know, so they argue that their performance could lower the team grade because they know less than their team members." (ASYM-SSKILL)
>
> "Some students often tell me that they are ashamed to ask such basic questions because many classmates already know much more than them. For instance, one student told me . . . I do not know how to derive a function, and my classmates talk already about how to integrate functions. No way to ask anything else . . ." (ASYM-SSKILL)

The asymmetries in students' social behaviors also limit collaboration and teamwork. In turn, professors have the demanding task of finding ways to help students work together despite their social fears. Thus, professors need to handle these differences and propose using teamwork strategies that describe the collaborative efforts of a group of students to achieve a common goal or to complete a task most effectively and efficiently. The specific strategies are leveraging complementary skills, defining work agreements, providing continuous feedback, and using students' co-evaluation to promote social safety environments and, in turn, social integration that facilitates the practical collaborative work needed in PBL. Initially, professors proposed leveraging complementary skills by putting students together with different skills to learn from these differences and acknowledge their strengths. For instance, some students from technical schools show less mathematical and scientific knowledge; however, they are very good at prototyping solutions. Thus, professors match these students with others who show better scientific knowledge. Students must assign roles according to their strengths to promote everyone to succeed in their assignment and contribute to team's goals' achievement. These initial role configurations foster everyone's social safety perception and acknowledge the benefits of diversity and complementarity in teams. After these first achievements, professors require students to interchange roles throughout the project.

> "For instance, students from industrial (technical) high schools are great at making models; they always find a way to fix mechanical problems, whereas students from other schools quickly understand the concepts behind the prototypes. So, in the first tasks, I seek to assign students roles where everyone can shine . . . After this first task, students from technical schools start to ask more. So, it is fundamental that students work together and help them to reinforce the others' complementary competencies." (MECH-COMPSKILL)

Additionally, other professors also make students define work agreements, where students explicitly define how they are going to work together, as well as their expectations and restrictions. Specifically, in these agreements, students set goals, identify strengths, and establish contact information, among other tasks. According to professors, this definition can reduce uncertainty concerning the relationships within a team, making it clear who is accountable for each task and what behaviors are allowed. Professors argue that higher certainty about roles, responsibilities, and working rules can diminish errors of judgment and biases. Moreover, such certainty may provide expectable behaviors and foster trust among students. In turn, the consequences of social actions are more predictable, which can augment social safety. Here, there are some visible behavioral clues that support the professors' perceptions:

> "Before I used the working agreements, there was more conflict within teams. Now, every team establishes a working agreement where team members clearly define responsibilities and roles. For instance, they fill [in] a logbook where every two weeks they register who performs what task. So, they often tell me there is no space for misunderstandings. They also state that clear initial agreements help them to avoid conflicts." (MECH-AGREE)

Alternatively, other professors proposed to provide continuous feedback about students' social performance to guide students on teamwork and communication skills. According to the professors, this constant reinforcement also promotes safe social interaction among group members. To illustrate this, professors said:

> "Continuously, I give team members feedback about what they are doing well regarding their behavior as a team. For instance, I especially encourage team members to support and encourage their quieter team members to speak up. Additionally, I often ask people from UIDIN (a unit that supports engineering teaching) for advice and invite them to talk about how to develop teamwork and communication skills. Often teams [welcome this feedback], they argue it is useful to handle their social problems because the project is very stressful." (MECH-FEED)

Finally, other professors used students' co-evaluation, where each student assesses the performance of their teammates. This co-evaluation process helps to foster students' involvement, since it helps avoid opportunistic behaviors. For example, the professors suggested:

> "Usually, I ask for peer co-evaluation. Every two weeks. Students have to share what they think they are doing well or wrong. Students like this practice. They often tell me this practice is useful because it fosters continuous speaking up about the problems. So, the problems do not get bigger. . ." (MECH-COEV)

4.3 Student Engagement Asymmetries

Last, professors also posit that there is an asymmetry in students' level of engagement in their majors. Professors argue that students from low-income families who join engineering faculties are usually the best of their high schools. However, when they face the first assessments, they often fail in most of them, or even fail the entire semester, making them acknowledge their relevant math and scientific gaps. Professors suggest these disappointing initial results seem to raise students' frustration and doubts about their ability to study engineering, discouraging their commitment to persevere with their studies and favoring dropouts from their majors. In other words, professors propose that the poor initial results obtained by these students seem to decrease their self-competence perception and thereby diminish their engagement with their majors. Here, there are some visible behavioral clues that support the professors' perceptions:

> "Usually, by the middle of the project, a [significant] number of students have dropped out of the course. So, when I ask them why, students answer that they have failed in all the other courses, and they are not sure if they are able to overcome the difficulties of the university." (ASYM-ENG)

> "More than once, students have told me, 'I was the best in my school, and now I don't understand anything. I have an F in every single test.' " (ASYM-ENG)

Therefore, professors have to deal with high attrition rates in their courses, and they need to reassign team members in diverse projects. Professors propose mechanisms that increase students' identification with their environment and experiences that may help improve their engagement and motivation for persevering in their majors. Specifically, professors suggest using authentic and local projects, the participation of practitioners, and the involvement of older students as teaching assistants to achieve this aim. Professors suggest that PBL allows students to tackle real and close issues early. This experience promotes students' involvement because they realize what they could do in the future and how to contribute to their environments. Moreover, professors have discovered that, when faced with authentic problems, students that initially show higher gaps also confirm that their performances can be equivalent to those of more initially skillful students, increasing their perception that they can develop the necessary skills to carry out that profession. For instance, some professors argued:

> "Last year, I worked on a project to improve hydroponic systems for local farmers who cultivate in a very desertic area. Students were so motivated and delighted when they realized the potential of their work for the local community. They told me that the project helped them realize what they can do in the future and like it. So, it was worth it to try to surpass the terrible math and physics courses . . ." (MECH-PROJ)

Nevertheless, it is relevant to consider that professors recommend using simplified and adapted authentic projects, limiting the problem characteristics to make them more suitable for all students' capabilities and facilitating the professors' management, whilst always maintaining some sort of authentic experience.

Additionally, professors also recommended inviting practitioners to tell their life lessons to students. They specifically recommended asking former students, which increases the likelihood that students will identify with their experiences and can improve their self-confidence perception by recognizing that students like them can overcome the complexities of their first years. Higher self-competence promotes enthusiasm and motivation to persevere in their studies. One professor gave an example:

> "I usually invite practitioners from the mining companies to give students feedback about their projects. These are very engaging moments because practitioners not just talk about the projects, but often talk about their working and university experience, and students tell me they can mirror them, especially when practitioners are our former students." (MECH-PRACT)

Finally, professors also suggested hiring older students as teaching assistants. This last strategy has been highly beneficial, since older students provide continuous guidance and support for students with technical and relational drawbacks. For instance, one professor argued:

> "Every semester, I have one former student that supports three projects. They help the fresher students continuously during the project. The fresher students feel closer with the assistants, thereby they ask questions and concerns. They also argue they use the same shorthand language, thereby it is easier to understand them. Assistants also help me by alerting me when a team or specific students need extra help. I could not work without my teaching assistants." (MECH-ASSIST)

5. Discussion

This study's results partly revealed the challenges that engineering staff in Latin America face due to social inequalities. Based on a sample of professors from a Chilean engineering faculty that implemented PBL in fresher courses, we identify specific barriers that emerge from social inequalities. Moreover, the study acknowledges strategies to tackle these barriers: scaffolding, teamwork strategies, and identification mechanisms.

This study's results contribute to previous contextual studies about the challenges of implementing PBL. Diverse authors have proposed that PBL implementation can be very demanding because, for instance, professors need to change how they teach and interact with students [39] or design assessment methods that examine diverse types of students' technical and transferable skills. Nevertheless, a few studies have examined how the environment can leverage or diminish these challenges. For instance, Zhou and Zi (2015) proposed that respect for authority in China induces students to follow the requirements of authority without question, limiting the students' questions or discussions required by PBL environments[40]. We expand this emergent stream of literature by providing evidence of the contingent effects of Latin American social inequalities on PBL in an engineering faculty. This contingent approach is relevant because it can help adapt the PBL method according to circumstances and increase its effective implementation.

Moreover, due to increasing international collaboration, studies have reported some challenges related to culture and background differences [41]. Nevertheless, these studies have focused mainly on cultural differences, acknowledging that people from diverse countries have different ways of thinking [21] or languages that may make it challenging to work in teams [42]. Our results contribute to this stream of literature by proposing that within the same culture, social and economic inequalities can also raise barriers to PBL implementation.

This study also provides practical insights for engineering professors on how to generate scaffolding, teamwork, and identification mechanisms for handling these challenges when they implement PBL in this context. Professors can use data availability, knowledge capsules, templates, and feedback as scaffolding to help students level their technical drawbacks and make the leveling process more efficient. Moreover, we propose to use the students' asymmetries as a resource to increase social safety by leveraging the complementary competencies using a teamwork strategy. Finally, we posit that mechanisms that raise students' identification promote students' enthusiasm and motivation to engage in their major and overcome any initial difficulties. These strategies can be helpful for others implementing PBL in similar contexts.

Although the professors' perspectives used in this study facilitate the identification of students' challenges in these contexts and the understanding of practices that professors can use to help students overcome the challenges, it only provides a partial view of the phenomenon. To understand this phenomenon more comprehensively, it is necessary to directly ask the students' opinions on what challenges, barriers, and difficulties they have met in PBL. In turn, future research should focus on interviewing or surveying students to validate the propositions presented in this article and to incorporate aspects that the professors may have overlooked.

Another limitation of this study is that it was restricted to a case study focused on a particular type of engineering school. Although these schools share similar characteristics with other engineering schools in similar contexts, there is a clear scope for examining such effects in other engineering schools to ensure the generalization of these findings. Thus, future studies may use quantitative methods to validate the proposition made in this exploratory study.

6. Conclusion

The engineering education community mainly agrees about the effectiveness of PBL to develop personal and interpersonal skills in engineering students. Nevertheless, contextual social conditions can affect the implementation of this methodology. In many cases within Latin America, fresher students show knowledge, skills, and engagement asymmetries that stem from the social inequalities that limit the achievement of the full potential of PBL. This study proposes that students can deal with these limitations through scaffolding, teamwork strategies, and identification mechanisms. Understanding the contextual conditions of engineering communities is relevant for practitioners because it can help adapt the teaching-learning methods according to circumstances, thereby increasing its effective implementation.

References

1. K. Brundiers and A. Wiek, Do we teach what we preach? An international comparison of problem- and project-based learning courses in sustainability, *Sustainability (Switzerland)*, **5**(4), pp. 1725–1746, 2013.
2. J. S. Krajcik and N. Shin, *Project-Based Learning*, in The Cambridge Handbook of the Learning Sciences, 2nd ed., R. K. Sawyer, Ed. Cambridge: Cambridge University Press, pp. 275–297, 2014.
3. A. Kolmos, Yun Du, Xiang, M. Dahms and P. Qvist, Staff Development for Change to Problem Based Learning, *International Journal of Engineering Education*, **24**(4), pp. 772–782, 2008.
4. C. K. Y. Chan, Facilitators' perspectives of the factors that affect the effectiveness of problem-based learning process, *Innovations in Education and Teaching International*, **53**(1), pp. 25–34, 2016.
5. H. Wan, W. Anthony and S. William, Introducing PBL in Engineering Education: Challenges Lecturers and Students Confront, *International Journal of Engineering Education*, **33**(3), pp. 974–983, 2017.
6. J. Chaparro-Peláez, S. Iglesias-Pradas, F. J. Pascual-Miguel and Á. Hernández-García, Factors affecting perceived learning of engineering students in problem based learning supported by business simulation, *Interactive Learning Environments*, **21**(3), pp. 244–262, 2013.
7. J. Chen, A. Kolmos and X. Du, Forms of implementation and challenges of PBL in engineering education: a review of literature, *European Journal of Engineering Education*, **46**(1), pp. 90–115, 2020.
8. S. Arancibia, K. Ayma, C. Cifuentes and N. Yañez, Representaciones Sociales Sobre Calidad y equidad en educación, *Salud & Sociedad*, **3**(3), pp. 293–311, 2012.

9. Centro de Estudios Públicos (CEP), https://www.cepchile.cl, Accessed 10 october 2020.
10. B. Pérez and Á. L. Rubio, A Project-Based Learning Approach for Enhancing Learning Skills and Motivation in Software Engineering, in *Proceedings of the 51st ACM Technical Symposium on Computer Science Education*, Portland OR USA, pp. 309–315, 2020.
11. X. Du, A. Kolmos, M. A. Hasan, C. M. Spliid, N. E. R. Lyngdorf and Y. Ruan, Impact of a PBL-Based Professional Learning Program in Denmark on the Development of the Beliefs and Practices of Chinese STEM University Teachers, *International Journal of Engineering Education*, **36**(3), pp. 940–954, 2020.
12. A. van Barneveld and J. Strobel, Reports from teaching practice: experiences and management of tensions encountered with PBL implementations in the early years of undergraduate engineering education, in *Proceedings of the Research in Engineering Education Symposium 2011 – Madrid*, pp. 1–6, 2011.
13. S. Aldabbus, Project-Based Learning: Implementation & Challenges, *International Journal of Education, Learning and Development*, **6**(3) pp. 71–79, 2018.
14. G. Lutsenko, Case study of a problem-based learning course of project management for senior engineering students, *European Journal of Engineering Education*, **43**(6), pp. 895–910, 2018.
15. D. Santos-Martin, J. Alonso-Martinez, J. Eloy-Garcia Carrasco and S. Arnaltes, Problem-Based Learning in Wind Energy Using Virtual and Real Setups, *IEEE Transactions on Education.*, **55**(1), pp. 126–134, 2012.
16. C. Zhou, J. D. Nielsen and A. Kolmos, Foster creative engineers by PBL: A case study of student satellite project (AAUSAT3) at Aalborg University in Denmark, in *2011 2nd International Conference on Wireless Communication, Vehicular Technology, Information Theory and Aerospace & Electronic Systems Technology (Wireless VITAE)*, Chennai, India, pp. 1–5, 2011.
17. A. M. Clyne and K. L. Billiar, Problem-Based Learning in Biomechanics: Advantages, Challenges, and Implementation Strategies, *Journal of Biomechanical Engineering*, **138**(7), pp. 1–9, 2016.
18. T. Kunberger, Revising a design course from a lecture approach to a project-based learning approach, *European Journal of Engineering Education*, **38**(3), pp. 254–267, 2013.
19. E. Marti, A. Gurguí, D. Gil, A. Hernández-Sabaté, J. Rocarias and F. Poveda, PBL On Line: A proposal for the organization, part-time monitoring and assessment of PBL group activities, *Journal of Technology Science Education*, **5**(2), pp. 87–96, 2015.
20. A. A. Ahern, A case study: Problem-based learning for civil engineering students in transportation courses, *European Journal of Engineering Education*, **35**(1), pp. 109–116, 2010.
21. K. E. Bledsoe and L. Flick, Concept Development and Meaningful Learning Among Electrical Engineering Students Engaged in a Problem-Based Laboratory Experience, *Journal Science Education and Technology*, **21**(2), pp. 226–245, 2012.
22. I. Gratchev and D.-S. Jeng, Introducing a project-based assignment in a traditionally taught engineering course, *European Journal of Engineering Education*, **43**(5), pp. 788–799, 2018.
23. J. C. Williams, W. A. M. Alwis and J. I. Rotgans, Are tutor behaviors in problem-based learning stable? A generalizability study of social congruence, expertise and cognitive congruence, *Advances in Health Sciences Education*, **16**(4), pp. 505–515, 2011.
24. J. Dong and H. Guo, Effective Course Redesign Strategies to Integrate Collaborative PBL in Senior Computer Engineering/ Computer Science Courses, in *2014 ASEE Annual Conference & Exposition Proceedings*, Indianapolis, Indiana, pp. 24.454.1–24.454.14, 2014.
25. R. McQuade, S. Wiggins, E. Ventura-Medina and T. Anderson, Knowledge disagreement formulations in problem-based learning tutorials: balancing pedagogical demands with 'saving face,' *Classroom Discourse*, **9**(3), pp. 227–243, 2018.
26. S. Chakrabarty and N. Mohamed, Problem Based Learning: Cultural Diverse Students' Engagement, Learning and Contextualized Problem Solving in a Mathematics Class, *World Conference on Integration of Knowledge (WCIK 2013)*, Malaysia, pp. 38–49, 2013.
27. L. Marteleto, D. Gelber, C. Hubert and V. Salinas, Educational Inequalities among Latin American Adolescents: Continuities and Changes over the 1980s, 1990s and 2000s, *Research in Social Stratification and Mobility*, **30**(3), pp. 352–375, 2012.
28. S. Donoso-Díaz, Reforma Y Política Educacional En Chile 1990-2004: El Neoliberalismo En Crisis, *Estudios pedagógicos (Valdivia)*, **31**(1), pp. 113–135, 2005.
29. J. P. Valenzuela, C. Bellei and D. de los Ríos, Socioeconomic school segregation in a market-oriented educational system. The case of Chile, *Journal of Education Policy*, **29**(2), pp. 217–241, 2014.
30. F. Torche, Economic crisis and inequality of educational opportunity in Latin America, *Sociology of Education*, **83**(2), pp. 85–110, 2010.
31. R. Graham, *Snapshot review of engineering education reform in Chile*, Alborg University/Pontificia Universidad Católica de Chile, Santiago de Chile, pp. 1–64, 2017.
32. A. Bernasconi, Free Tuition in Chile: A Policy in Foster Care, *International Higher Education*, **98**, pp. 8–10, 2019.
33. E. F. Crawley, J. Malmqvist, S. Östlund, D. R. Brodeur and K. Edström, *Rethinking Engineering Education: The CDIO Approach*, Springer International Publishing, pp. 11–45, 2014.
34. K. M. Eisenhardt, Building Theories from Case Study Research, *Academy of Management Review*, **14**(4), pp. 532–550, 1989.
35. D. R. Thomas, A General Inductive Approach for Analyzing Qualitative Evaluation Data, *American Journal of Evaluation*, **27**(2), pp. 237–246, 2006.
36. Ú. Beagon, D. Niall and E. Ní Fhloinn, Problem-based learning: student perceptions of its value in developing professional skills for engineering practice, *European Journal of Engineering Education*, **44**(6), pp. 850–865, 2019.
37. *ATLAS.ti*. 2018.
38. V. Braun and V. Clarke, Using thematic analysis in psychology, *Qualitative Research in Psychology*, **3**(2), pp. 77–101, 2006.
39. D. Kokotsaki, V. Menzies and A. Wiggins, Project-based learning: A review of the literature, *Improving Schools*, **19**(3), pp. 267–277, 2016.
40. C. Zhou and J. Shi, A Cross-Cultural Perspective to Creativity in Engineering Education in Problem-Based Learning (PBL) between Denmark and China, *International Journal of Engineering Education*, **31**(1), pp. 12–22, 2015.
41. K. D. Beddoes, B. K. Jesiek and M. Borrego, Identifying Opportunities for Collaborations in International Engineering Education Research on Problem- and Project-Based Learning, *Interdisciplinary Journal of Problem-Based Learning*, **4**(2), pp. 7–34, 2010.
42. K. Khalaf, S. Balawi and G. W. Hitt, Engineering Design Education: When, What, And How, *Advances in Engineering Education*, **3**(3) pp. 1–31, 2013.

43. UCN Management Platform, https://inb.ucn.cl/baini.html, Accessed 10 October 2021.
44. UCN BI Statistics, https://bi.ucn.cl/statistic/PRE-04, Accessed 10 October 2021.

Appendix A

Figs. 1 and 2 show the retention rates in the second and third years from 2016–2020.

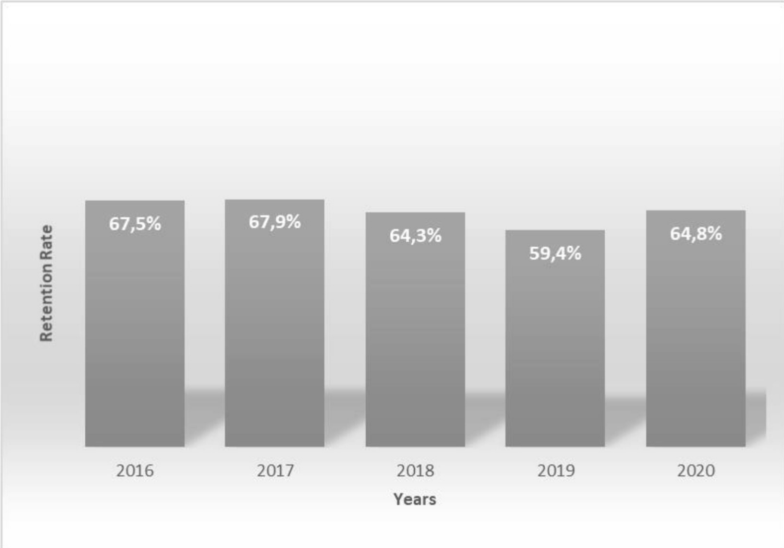

Fig. 1. The retention rate of the second year in the UCN Engineering Faculty [43].

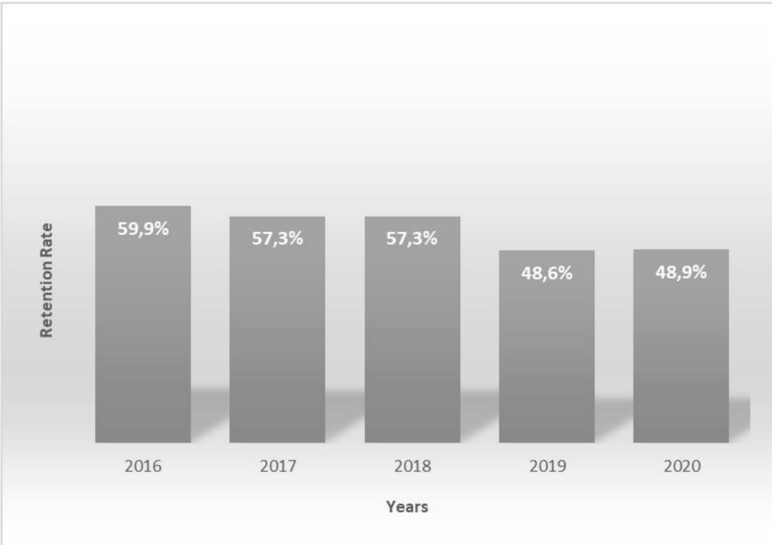

Fig. 2. The retention rate of the third year in the UCN Engineering Faculty [44].

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