How to teach teamwork in a PBL curriculum

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Abstract

The needs of the globalized world and the transformations that different organizations undergo make being competent in teamwork a necessity. Therefore, the education sector must give it the appropriate relevance and concern itself with developing this particular competence in higher education. A Colombian university has a course called Engineering and Science: A Shared World, which has a PBL curriculum and aims to train this competence explicitly. The course design included a theoretical presentation on what a team is and its main characteristics, postulated by Johnson, D.W., Johnson, R., & Smith, K. (1998), and activities to evidence these characteristics and their importance to work adequately. This text presents a case study that seeks to identify the learning outcomes related to teamwork within the PBL proposed in this course. To achieve this, qualitative information was collected through the products created during the course: the class activities, the contracts, a group of team health activities, the final reflections, and the co-assessments. This information was analyzed through predetermined categories based on the course objectives and the dimensions of teamwork; no new categories emerged. The data analysis revealed that students identified and conceptualized elements such as individual responsibility or face-to-face interaction properly and as essential for team building and development. Still, positive interdependence and a proactive approach to communication and conflict were challenging to conceptualize and exemplify. Finally, many of the students identified that although team monitoring activities were carried out in class concerning the progress of socio-emotional skills, such as anticipating conflict or managing agreements, it was new for them. Their teams did not take full advantage of these spaces that, reflecting on the entire process, were as important as monitoring the products to be delivered.

Keywords: Teamwork competency, Engineering PBL, Higher education, Qualitative research

1. Introduction

Multiple aspects have radically shaped and changed the demands on the competencies students must develop through their university studies. In the last 15 years, different authors have attributed these changes to highly complex phenomena such as technological and industrial advances, the development of new specializations in all fields of knowledge, globalization, and the need for interdisciplinarity to solve complex

problems, among others (Wnag et al., 2024; Galloway, 2007; Gaskins et al., 2015). Unfortunately, these changes have revealed multiple inconsistencies between the competencies required by a rapidly changing society and the competencies developed by higher education programs.

The benefits of teamwork encompass various characteristics that allow any institution to advance its objectives quickly and effectively. For example, teamwork enables the creation of new and disruptive ideas through co-creation, incorporating different perspectives, experiences, and diversity that contribute to creativity and innovation in the workplace (Tucker & Abbasi, 2012). Furthermore, the exchange of ideas and the scalability of the ways of thinking of several people with different skills and knowledge allow for the resolution of highly complex problems presented by a highly globalized and developed world—problems that would take a disproportionate amount of time for a single person to solve. Likewise, teamwork enables social and inclusive sharing, increasing participants' morale (self-perception) and creating a system in which the quality of work, efficiency, and effectiveness increase in direct proportion to the underlying trust and empathy within the team (Katzenbach & Smith, 1993). Therefore, the education sector must give it appropriate importance and consider how to develop this particular competency in higher education.

However, a common phenomenon in developing this and other competencies is that lectures and passive interactions between students are insufficient to foster the development of a competency as complex as teamwork (Passow & Passow, 2017). On the contrary, competency development requires active learning, commonly described as carefully designed activities to ensure student engagement and motivation (Felder & Brent, 2016).

Additionally, there is a lack of accuracy and explicit elements when developing teamwork in a higher education classroom. On the one hand, teachers commonly understand teamwork as any activity developed in groups of students within an educational context, as well as an underestimation among teachers and students about the true nature of competence. On the other hand, many teachers mistakenly believe that exposing students to different work activities with their peers can implicitly lead them to develop teamwork. However, research in the field has shown that the absence of explicit theorizing about teamwork and its characteristics can inevitably lead to an inferior understanding of the topic, with subsequent unfavorable performance of the competency (Goldsmith et al., 2024; Pinard et al., 2017; Therrien et al., 2017).

Unfortunately, the two scenarios described above lead to unpleasant experiences for students and, in general, a bad perception of working with peers. This is due to a poor understanding of what teamwork competence is, which leads to an overload of work for teachers, conversations within teams without a harmonious solution, and the so-called "free riders" phenomenon (individuals who transit for a while without contributing to the team and who benefit from the product of others). For example, Marin-Garcia (2008) describes how these factors affect teamwork in higher education students, who consider this type of activity overwhelming and challenging to manage within the allotted time, especially when teachers expect high-quality products from the teams.

Considering these two essential aspects, teachers who wish to develop this critical competence must be involved in active team supervision and management processes. Their central role is to generate scenarios where students can create a series of processes they are not accustomed to performing. Such an intricate task can be carried out successfully when efforts are oriented to provide a set of theoretical and practical activities related to teamwork competency; at the same time, students are sensitized to the importance of working harmoniously with their peers towards achieving objectives. This implies the need to align the teaching of competence with the curriculum (Biggs & Tang, 2011) by generating learning objectives, class activities, and assessments that truly allow students to learn about it.

In this sense, the first step is defining what teamwork means. There are various definitions in the literature, but in this document, we adopt the one made by Los Andes University in 2023: "Interact cooperatively with others to achieve common goals, recognizing the richness of individual differences and promoting equity and co-responsibility". It recognizes the institutional values and particular bets for its programs' curricula, shows that it is a process over time where students interact dynamically, and the result of their work depends not only on their individual qualifications but also on their ability to synchronize their actions, coordinate efforts, and establish effective communication to achieve common goals.

For this reason, curricular initiatives like PO-PBL are the ideal space for teaching teamwork. However, organizing student groups is not enough; pedagogical approaches are required to encourage them to collaborate in ways that transform them from a group of people working together into a team. Dahms et al. (2017) present that in the first-year curricula of the Faculty of Engineering and Science at Aalborg University, students take a course that includes specific activities that allow them to reflect on their experience in the projects. They also acquire tools to analyze the organization of teamwork to identify strengths and weaknesses, enabling them to propose improvements in similar future scenarios. However, these courses, which emphasize the need to explicitly develop pedagogical strategies for teaching teamwork, are not widely available in other programs. The purpose of this document is to identify the learning outcomes related to teamwork in a course that included a pedagogical design that explicitly introduces a theoretical presentation about what a team is and its main characteristics, postulated by Johnson, D.W., Johnson, R. and Smith, K. (1998), and activities to demonstrate these characteristics and their importance for adequate work in the development of the course project.

2. Context

"Engineering and Science: A Shared World" is part of a group of courses offered to all students at the University of Los Andes as part of their comprehensive education. Given its focus, the course explicitly addresses transversal competencies such as teamwork. The course has two objectives: First, by identifying the specificities of engineering and science as disciplines and their methods, students can analyze and propose multidisciplinary solutions to global problems associated with the SDGs. Second, students identify fundamental elements of teamwork competency and use tools to monitor their development throughout the course.

The course has one weekly two-hour session. During the first eight weeks, students complete two exercises using the 7-step PBL model (Wood, 2003) in loose groups. The goal is for students to meet several classmates; many deliverables are individual. In this phase, students delve deeper into the content associated with understanding engineering and science. Various activities are carried out to promote collaboration and peer assessment of products for grading. At the same time, the sessions put into practice some of the elements proposed by Johnson, D.W. et al. (1998) for collaborative work, which are the foundation of teamwork.

In week 8, students work in pairs to develop an initial conceptualization of the elements proposed by Johnson, D.W., Johnson, R., and Smith, K. (1998) and use it to analyze one of the previous lessons in the course. These elements are: 1. Individual responsibility for tasks; 2. Positive interdependence; 3. Face-to-face interaction that promotes mutual support; 4. A proactive approach to communication and conflict; 5. Frequent self-assessment of team functioning. As Figure 1 shows.

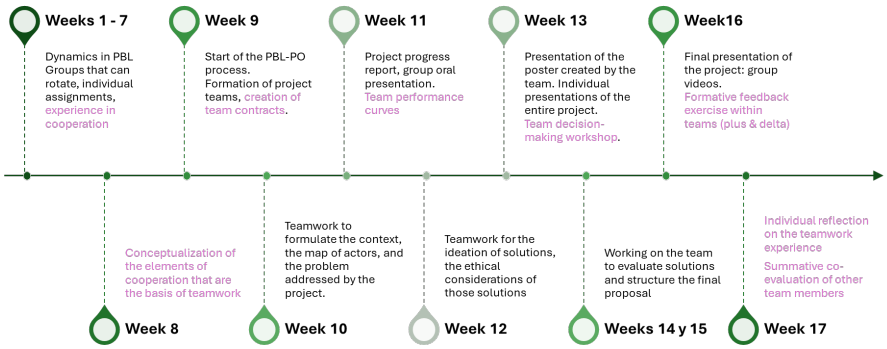

Figure 1. Weekly timeline of activities carried out throughout the course

In the second 8-week cycle, a project is developed using the PBL-PO model (Dahms et al., 2017; Hernández et al., 2016). Students, in fixed groups of 4 or 5, define a problem framed within a range of SDGs (Development of structures for housing, work, and recreation; Sustainable production of new foods; and Information management and security). They then propose alternative solutions through ideation processes, select some, and finally identify the knowledge required to implement the project in engineering, science, and other disciplines. The project has graded presentations every three weeks, and all team members must participate in these activities.

This phase uses the Hernandez and Gómez (2020) proposal to develop teamwork skills (Figure 2). This model takes Kolb's (1984) learning cycle and explicitly uses it throughout the project's development, drawing on the team's experiences between deliverables. Thus, each team experiences working together to produce a deliverable. This is followed by a process of individual and collective reflection on team functioning, seeking to develop element five proposed by Johnson and colleagues, and using questioning on elements 1 through 4. Teams are then asked to review their operating rules or elements that need adjustment to improve team functioning. This process occurs three times for the teams.

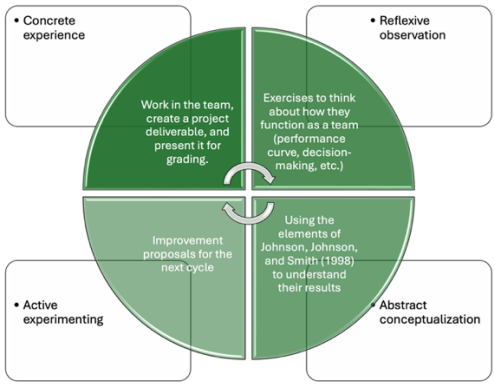

Figure 2. Model for experiential learning Teamwork (Hernández & Gómez, 2020) takes up Kolb's proposal and proposes explicit actions for students to reflect on the functioning of their team.

As Biggs and Tang (2011) suggest, assessment must be aligned to promote the learning desired by the instructor. In this case, teamwork evaluation is an independent component of the team's products. At the end of the project, a formative feedback activity is conducted within the teams (plus & delta) to express face-to-face the strengths and areas for improvement of each person on the team. Finally, summative evaluation using a rubric and a peer-review process by other team members. In this component, there is no grading by the professor, as the professor cannot fully demonstrate the relationships that develop within the teams.

The course closes by asking students to write a letter to a new student using the elements proposed by Johnson, Johnson, and Smith (1998) to share their experience working in a team in the course and offer advice for successful results. The research question arises: What learning outcomes related to teamwork do students in the course achieve?

3. Methodology

It is a descriptive study from a critical and hermeneutic perspective. This perspective enables understanding a phenomenon both globally and in detail, strengthening and consolidating a valid and pertinent discourse concerning the reality of the subject studied (Alvesson & Skoldberg, 2009; Goetz & Lecompte, 1988). This study's participants were 31 students organized into six teams. They were selected using a fixed sampling method: all the students enrolled in the course in the fall semester of 2024.

The data were collected from four sources: the documents produced in the classroom activities, the team contracts made when the teams were formed for the PBL-OP, the records of the team performance

curves written as part of a team performance monitoring activity, the final reflections (84.4% of students did it) and the final team co-evaluations documented with the tool used to carry them out (60% of the students did it).

The documents were organized and analyzed using the five elements of teamwork proposed by Johnson et al. (1998); they were triangulated to characterize the process of developing teamwork skills in students and to identify the skills learned. Finally, the relevant fragments were translated from Spanish to produce a narrative in English, so the fragment S1T4 means that it was written by student 1 of team 4. The results are presented below, highlighting the voices of the course participants for each category of analysis to provide evidence of the students' understanding of each and the progress they made during the course.

4. Results

Individual accountability for tasks means that each person is responsible for their own work and is accountable to the team for their development. To achieve this, it is essential that each individual's contributions be relevant to achieving the final objective and that they be known by all (Johnson et al., 1998). The analysis of the final reflections found that 26 students explained this element as the responsibility to complete assigned tasks concerning the final product of each delivery, for example, "...*each member was assigned clear responsibilities...there were times when some members did not have available time to meet, which slowed the group down. This aspect taught us the importance of regular reporting and ensuring everyone understood their contributions' relevance*." S1T4 or "*Each one assumed their specific tasks, developed them, and we communicated days before the deliveries to consolidate them correctly*" S3T3.

Three students expressed that individual accountability involves ensuring that other team members also know about each other's work: "*I understood that it is not only important to delegate tasks, but also to make sure that everyone is aligned with the common vision and with the final goals of the project.*" S5T5; and finally, two students related it to the responsibility to identify their skills to contribute better: "*There are people who prefer to lead, there are people who want to execute, there are people who are more creative, and there are people who are more analytical, it is your responsibility to find your strength and use it to help the group*." S1T1.

Positive interdependence refers to the understanding of each team member that their individual success is intrinsically linked to the team's. Each member recognizes that their contribution is unique and indispensable to achieving the common goal and that the team's progress depends on all efforts and collaboration. (Johnson et al., 1998). During the analysis, a significant group of students limited positive interdependence with shared responsibility and affected the team by not doing their part: "*This means, in other words, that not performing one's own task not only has negative implications for oneself but for the whole group*." S5T1.

Several reported not having experienced it in their team, but managed to identify that it was important to have a better performance: "*Everyone did their part separately, and we were unable to prepare a joint presentation. As a result, we ran out of time when it was time to present*" S2T1. Finally, some students defined it adequately: "*This sense of interdependence was clearly manifested when Student 1 struggled with a technical tool. Although we initially thought he should solve it alone, Student 4 and I offered to help him, which allowed us to learn something new in the process.*" S3T6 or "*bring ingredients to prepare sandwiches and share drinks. This exercise allowed us to observe how individual compliance affects the team: a sandwich without bread is just a salad, and one without protein is bread with vegetables. This example summarizes positive interdependence, an essential principle of teamwork. Each member took responsibility and delivered, making for a successful breakfast*." S5T6.

This element is complex, and some students narrate how they came to experience interdependence through taking a more active role in their team: "*The fact that everyone contributed different ideas and then*

discussed them helped a lot, including that of the final solutions taken was one of the ideas that I presented, which would not have happened if I had taken a passive attitude in the group." S3T4. Some identify that achieving these skills will be essential for their life: "*There will always be input from people who do not do the same as us, who do not think like us, who simply are not like us. That is why... a good team is better than an outstanding individual. Teamwork is crucial to solving challenges in our work lives, even our personal lives*" S4T3.

Face-to-face interaction that promotes mutual support refers to interactions established between members in which they encourage and facilitate the work of others to complete tasks and produce assigned work to achieve the planned objectives (Johnson et al., 1998). In this category, 26 students recognize this element of teamwork as crucial and express an understanding of the importance of good communication, which occurs most effectively in face-to-face interaction, for achieving common goals. It is another of the elements that are well-defined and characterized by the students. Figure 3 shows the results of this element for several of the teams. It can be identified that Team 4 best responded to the recommendation to generate spaces for face-to-face interaction and presented it as a fundamental element for its good performance. Other teams, such as Team 1, show that the difficulty of this type of interaction (prioritizing only written chat) made it difficult to move from the individual to the collective, impacting their progress as a team.

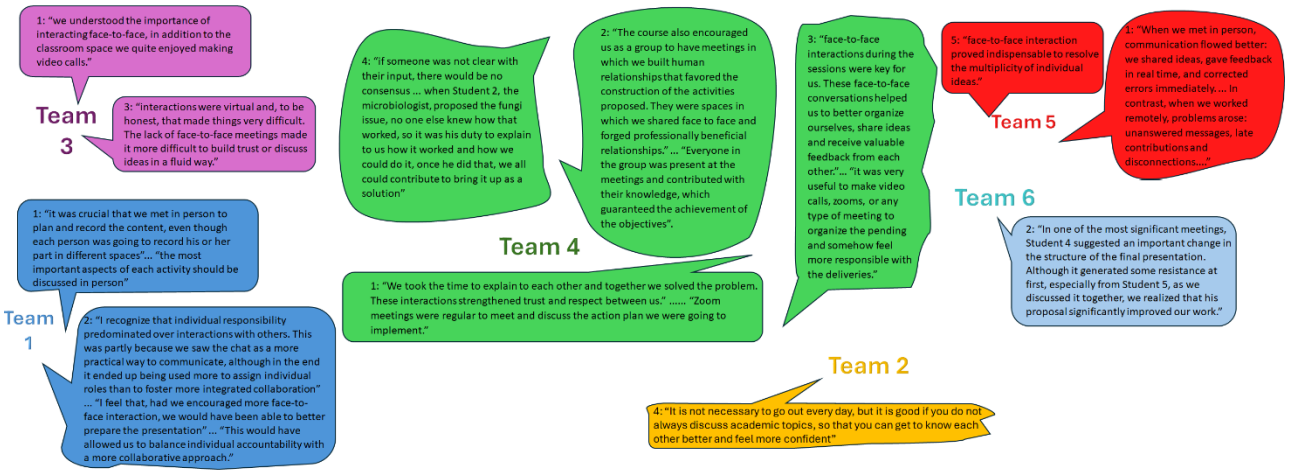

Figure 3. Results on Face-to-Face Interaction. Each team's balloons are a different color, corresponding to a different student's statement. Balloon density shows how many team members report on this element.

The proactive approach to communication and conflict management states that teams cannot function effectively if their members lack and do not use the necessary interpersonal skills. It is crucial for team members to know and trust each other and to communicate correctly and unambiguously. Each member needs to address conflict directly and constructively, helping to manage or resolve it in a way that strengthens team cohesion and effectiveness. Figure 4 shows excerpts from the student's reflections on this element. Team 6 reported having had conflicts that they could resolve through respect-based communication and expressing the value of each team member's contribution. In the same way, team 4 made it (although we do not present it in **¡Error! No se encuentra el origen de la referencia.**; however, in **¡Error! No se encuentra el origen de la referencia.** of the face-to-face interaction, they refer to conflicting moments).

The other teams reported having had no conflicts, and only a few students in each team referred to conflict situations, as seen in the figure for teams 1 and 2. Four people expressed that because they did not trust or know each other well, discussing mistakes was very difficult, and they noticed avoidance of discussing potentially conflictive situations. In this way, they, along with 22 students, confirm the importance of having a space for socializing to build trust and get to know each other, allowing them to have uncomfortable conversations that benefit a positive team atmosphere.

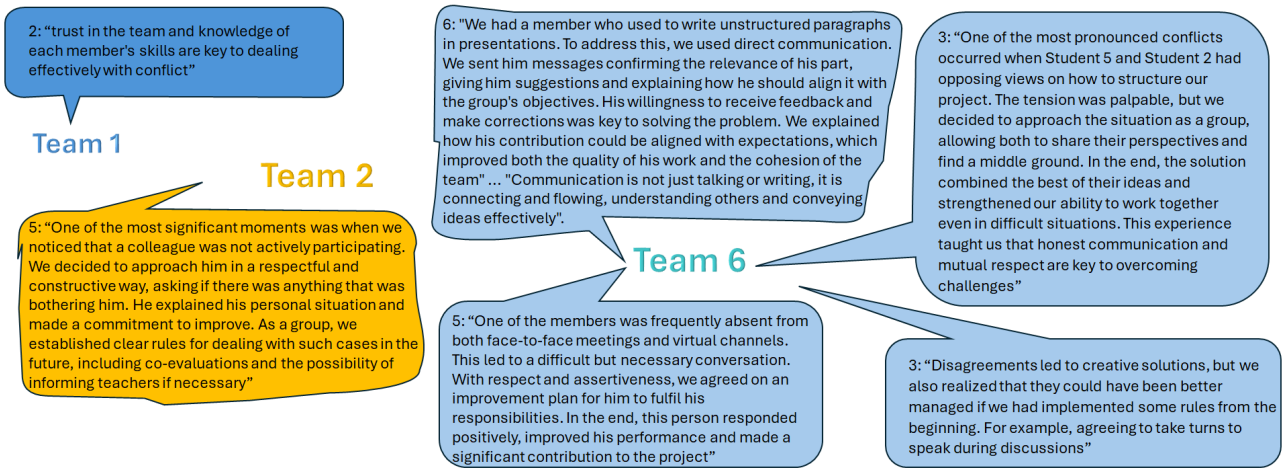

Figure 4. Results for the category "Proactive Vision" in Communication and Conflict Management. Each team's balloons are a different color, corresponding to a different student's statement. The balloon density shows how many team members report on this element.

Frequent self-evaluation of group functioning refers to the fact that groups need to set aside specific time to discuss how well they meet their objectives and maintain effective working relationships among their members. They should discuss their feelings about the team, their performance, the most valuable contributions, and what practices need to be strengthened or changed.

T1			
S1	S2	S3	S5
S2: S1 did a good job, fulfilled its responsibilities, and did it correctly.	S1: S2 completed all relevant activities and attended everything punctually and correctly. S2 made no mistakes in group work.	S1: S3 completed all activities, communicated well, and was respectful at all times.	S1: S5 completed all the tasks and could perhaps communicate a little more in meetings.
S3: You could communicate more and be more punctual, but you do good work and make good research.	S3: Everything was impeccable, and S2 was always punctual and responsible. She was a good leader, and without S2, many things would not have been accomplished.	S2: The work carried out was consistent and the dedication demonstrated individual responsibility, which contributed to cooperative work.	S2: S5 contributed to the work with individual responsibility, and his contributions met expectations. S5 also contributed his ideas to the group.
S4: A good teammate and willing to help. He contributed good ideas.	S4: Very good initiative in all the work	S4: A very good teammate, S3 contributed good ideas and was very responsible	S3: Good research and contributions
S5: Good teammate who actively participates in activities	S5: A good teammate who shows considerable initiative and participation during group activities.	S5: Good teammate who actively participates in activities	S4: Good teammember with a great work attitude.
Itself: I fulfilled all the necessary requirements for the class, completing all assignments and submissions on time. I communicated with my team and carried out all relevant activities.	Itself: I believe that my contributions to the work were timely and I kept an attention on its completion. Likewise, I tried to keep an eye on my group in their individually assigned responsibilities and fulfill my own as expected.	Itself: I can improve	Itself: More in-depth research is needed.

Figure 5. Segment of the co-evaluation of team 1, each column includes comments about the other team members. Green fragments are about communication, and red pieces are about individual responsibility for tasks.

The findings indicate that, in this element, students demonstrate a propensity to restrict the self-evaluation of team performance, opting instead for the collective assessment of each individual's contributions or outcomes: "*These sessions were not always easy, as they sometimes involved constructive criticism, but they always helped us move forward. In one of these reflections, we realized that some members were taking on a heavier workload than others, which led us to redistribute tasks more equitably.*" S2T6 or "E*very time someone contributed, they would ask for feedback from the group and correct where necessary.*

Before any major deliverable, we would review everything together to ensure we did not miss any mistakes." S1T6. This is also evident in a segment of Team 1's final co-evaluation shown in Figure 5.

Additionally, they illustrate the interconnection between team self-assessment and conflict management: "*Although we did not conduct formal self-evaluations frequently, we did reflect at key moments on how we were working as a team. For example, after deciding to exclude a member, we discussed how to avoid similar problems. Overall, our group functioned well, but I believe that more time spent on self-evaluation would have been beneficial to improve our dynamic" S3T3 further*. The ability to manage conflict is a complex skill, and evasion is a common strategy employed in some situations: "*This was one of the aspects that we practiced the least and that, in retrospect, could have improved our performance the most ... On the few occasions we did, we identified problems such as a lack of clarity in responsibilities, but we did not implement significant changes*." S1T4.

Furthermore, the results obtained demonstrate the efficacy of targeted reflections in fostering self-evaluation among teams. This process, however, is recognized to present challenges. Nevertheless, it is acknowledged that it contributes to an enhanced awareness amongst students regarding the significance of this component: "It is *difficult to have sincere conversations with people you know very little about. So, out of a desire to look good, none of us could talk about our obvious flaws as a group. Everything was discussed superficially"… "The only time we discussed the goals achieved by the group was when we had to place our group on a teamwork curve in class*" S4T2.

It was reported by both Teams 4 and 5 that this was the element with which they had worked least extensively during the course: "A*fter the delivery of activities, we always had a space to give a little feedback either in class or through the group we had on WhatsApp ... I insist that we did not have much communication in person, nor did we integrate with activities that were not academic, which for me represents a shortcoming.*" S1T5

In Team 1, the health spaces and activities designed for the class are used as spaces for self-evaluation as a team: "*In the last class, we did an activity called "Plus and Delta", where each team member had to give two positive aspects (Plus) and two aspects to improve (Delta) to each teammate ... the observations helped me to reflect and identify areas where I can improve*" S4T1. However, their colleagues have posited that if more of these activities had been carried out, the team performance would have been enhanced: "*It would be ideal to have established regular face-to-face or virtual meetings to plan and monitor the progress of each stage of the work. This way, we could have detected potential problems and adjusted our strategy to deal with them effectively*." S2T1.

As demonstrated in Figure 6, the results of the teams' performance curves indicate that the teams identified for enhancement just fulfilled compliance with the roles (none of them modified the initial contracts) and required additional time for the course topics. This would entail meeting overtime as stipulated in their contracts.

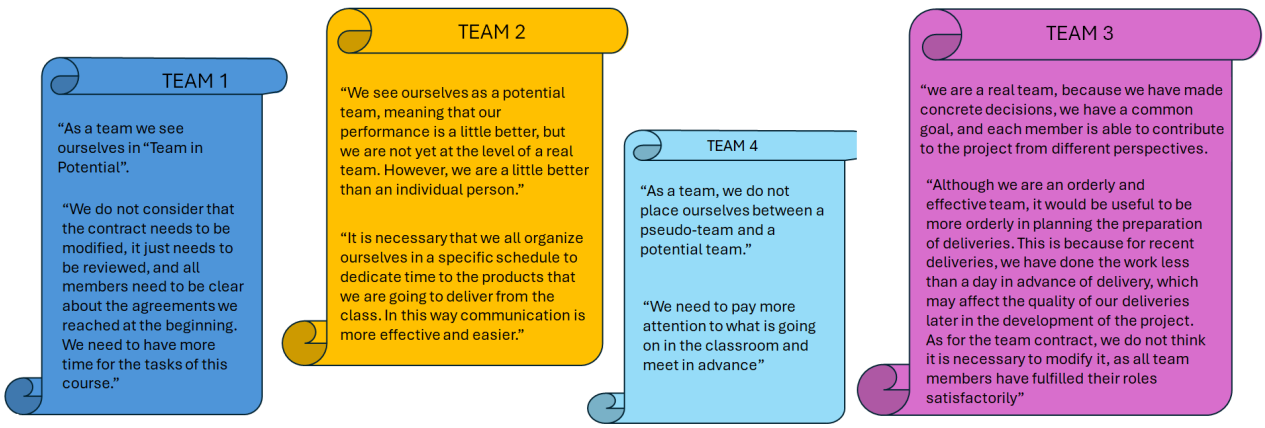

Figure 6. Results of equipment performance curves.

5. Discussion

The triangulation of the data shows that throughout the course, students identified and conceptualized the main characteristics of teamwork. The two elements most students adequately conceptualized were individual responsibility and face-to-face interaction, considering them essential for team formation and development. Regarding positive interdependence, the conceptualization is less clear and is often easily related to shared responsibility, which affects the team but not to better collective construction. Regarding communication and conflict management, most students considered it very important and beneficial to have spaces for collaborative building and generating trust, allowing them to have difficult conversations in a better team environment. Regarding the last element, frequent self-evaluation of group functioning, many students identified that, although team monitoring activities were carried out in class on the progress of socio-emotional skills, such as conflict anticipation or agreement management, this was new to them. Their teams did not take full advantage of these spaces, which, when reflecting on the entire process, were just as important as monitoring deliverables.

These learning processes occur through concrete reflection on the processes they experience, as proposed by Kolb (1984). These reflections show that learning can happen in two pathways: the first occurs when students are part of a team where these characteristics are incorporated. The monitoring and dialogue processes are more effective, so they appropriate the skills. The second occurs when team interaction is not necessarily effective, but students can identify which characteristics could be improved and should be implemented in new processes. In this case, the experiential learning strategy proposed by Hernández and Gómez (2020) allows students to advance their understanding of teamwork, from the collective development of products to a complex skill that involves coordination to achieve a common goal.

This does not imply that all teams are successful or that they achieve the best experiences. However, it does show that, as Biggs and Tang (2011) suggest, curricular alignment is essential to promote specific learning outcomes in students. In this particular course, the design of the deliverables that all team members must submit orally and team health activities, such as the construction of performance curves or individual formative peer assessments (plus-delta), allow for reflection on team functioning and the learning of teamwork skills. This completely transforms students' experience with teamwork, distancing them from the negative experiences of working in groups without guidance or explanation about what teamwork is, what its elements are, and how it is managed internally, as described by Goldsmith et al. (2024).

Finally, students recognize that communication and active participation in meetings are essential for team performance, as they foster a more collaborative environment where there is trust to participate. At the same time, as Katzenbach and Smith (1993) suggest, a high level of trust is an indispensable component of an honest and beneficial self-assessment, and it is these internal assessments within the team that allow them to achieve better organization and self-management increasingly. Therefore, this pedagogical design, incorporated into several courses, would strengthen the learning of this competency through specific peer assessments on teamwork skills.

6. Conclusions

From all the results presented, the design of activities aligned with the learning objectives, particularly in the case of teamwork, is key to ensuring competency-based learning. Activities should include individual reflections and group peer assessments so that students recognize and place greater importance on face-to-face interactions to work on consolidating their deliverables, strengthening personal interactions, and generating an environment of team trust that allows conflict resolution and avoidance.

Positive interdependence was evident as an element that is not easy to understand and is one of the elements that requires the most time to understand. The students' reflections show that building an environment of trust within teams is potentially the space where self-assessment of team functioning and,

consequently, the construction of positive interdependence can be improved. This is closely linked to the quantity and quality of face-to-face interactions that can be encouraged.

Therefore, this case study contributes to the creation of curricula or course programs that explicitly include teamwork development. Carrying out activities that explicitly involve teamwork allows for the conceptualization and development of this competency and avoids negative experiences resulting from inadequate support and guidance in team building. This is a common practice when teachers only assign group work but do not explain or provide advice on what teamwork is and how to work as a team.

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