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Student Perceptions of Formative Assessment and Cooperative Work on a Technical Engineering Course

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Abstract: Formative Assessment and Cooperative Work (FACW) is a teaching methodology that promotes student learning based on peer support, both in solving problems and identifying the mistakes made through feedback. The perceptions of 49 mechanical engineering students at the University of Burgos are analyzed in this article with regard to their first practical experience of FACW methodology in a technical subject, characterized by a highly complex content and a strong link between theoretical and practical concepts. The responses of the students to two blocks of open questions were evaluated in a qualitative, mixed, and statistical analysis. Various aspects that the students raised in relation to FACW could therefore be studied, such as their points of view towards: (1) The usefulness of FACW teaching modality; and (2) their preferences regarding the optimum teaching modality. The results showed that, although the students expressed favorable opinions towards FACW, they did not consider, in general, that teamwork was necessary for optimal learning, revealing a clear dependence on formal classroom presentations for the explanation of theoretical concepts. Students considered that theoretical concepts could not be autonomously acquired. Therefore, the application of the FACW teaching methodology to these courses could be especially beneficial to favor autonomous learning and to develop teamwork skills, training engineers with the right knowledge and skills today for tomorrow's world.

Keywords: formative assessment and cooperative work; active and collaborative learning; student-centered learning environments; technical engineering subject; mixed analysis; autonomy; teamwork skills; teaching guidance

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1. Introduction

Incessantly increasing demands within modern society in relation to professional, ethical, and environmental aspects [1] are prompting continual change within society, in relation to both personal and professional spheres of life. New stimuli are emerging every day, mainly connected to social networks [2,3], and, without any doubt, it is only through education that future professionals may adapt to all these changes, promoting the importance of teamwork and the transversality of knowledge, while encouraging autonomous and responsible decision-making [4]. These demands are especially prevalent, among others, in engineering professions where such aspects have assumed great importance [5].

The teaching modality that is used to educate students will have a direct impact on their future professional behavior and on their adaptation to the relentless pace of social changes [6]. If those aspects that relate both to teamwork and to the transversality of knowledge are promoted, at the same time as engineering students specialize in technical areas, then they will gain the necessary skills to respond as professional engineers to this new social framework [7]. Teaching guides on different subject areas certainly include these skills in the form of competencies [8], although whether students actually develop those skills will to some extent depend on the teaching modality. Nevertheless, it is quite clear that some of them will not be developed through formal classroom presentations, based on expository teaching strategies: The teacher explains all the theoretical and practical concepts to the students, who do not participate during the class [9].

The teaching modalities of technical subjects must therefore incorporate alternatives to formal presentations. Some of the most encouraging innovations over recent years have been limited to the use of new technologies and to continuous assessment on the basis of partial exams or projects, the latter as a result of the adaptation of the European Higher Education Area (EHEA) [10]. A teaching methodology that promotes autonomy, cooperative work, and clear perceptions of the surrounding reality is essential [11]. It is, moreover, an obligation of the university system, based on critical reflection [12], to provide students with the skills that are necessary for them to discern sound professional practice in society. So, it is likewise fundamental for students to acquire these capabilities that are required in society today, in the course of their education [13], which calls for a change in the way that technical subjects are taught. Change will not be easy, as it may be accompanied by a reduction in the range of concepts that are addressed in an engineering subject, although the scope of the area of competencies will be much more extensive [14].

Formative Assessment and Cooperative Work (FACW) is a teaching methodology that favors autonomous learning among students, in the absence of continuous support from the teacher, through group discussion between peers for a deeper understanding of the concepts explained in class and their practical application [15]. The students approach the resolution of theoretical and practical problems based on concepts briefly explained by the teacher [16] with the support of their peer group (fellow students). Firstly, there is the group approach to problem solving, so that every student can learn from peer group interaction [17]. Secondly, the work of each group is assessed by the other groups, with the idea that strong and weak points and mistakes addressed through the opinion of their peers, rather than the teacher, will lead participants to deeper reflection upon those points [18].

FACW also provides a more positive evaluation of the teaching activity by the students through closer teacher–student dialogues [19]. It promotes problem-based learning, in which the resolution of problems is addressed in a similar way to professional work [20], and student-centered learning environments, which gives the students greater decision-making capacity [21]. The learning of concepts related to sustainability, increasingly important in current society, can be addressed more widely through FACW, due to the intra-group debate regarding the optimal environmental solution of a certain problem raised by the teacher [22].

The performance of this teaching methodology can be enriched in several ways. For example, the use of new technologies favors the establishment of a common framework for group work [16,23], and personalized feedback of the group work by the teacher helps students to understand their mistakes from an objective perspective [24]. The teacher should be careful and precise with this feedback, indicating the negative aspects with a positive approach for genuine encouragement of continuous progress [25], and should focus on group functioning, rather than on the quality of the work presented, already assessed by the peers themselves (inter-group assessment) [26].

Notwithstanding the above, FACW also has some negative aspects. Firstly, the students may show reticence to depart from formal presentations, with which they feel more comfortable, although their acceptance of this teaching methodology will be easier, if an evaluation criteria consistent with the classroom assignments is established [27]. Secondly, some students may show a lack of respect for peer work, advancing assessments focused only on the negative aspects. The teacher must therefore question the motivation behind those assessments, so that they are eventually framed in such a way as to favor learning [28]. Lastly, some students may not collaborate on tasks and take full advantage of their peer work, so a method of evaluation that encourages individual knowledge acquisition is necessary [29].

All the aspects discussed above imply a need for acceptable teacher training, to ensure that the teachers have the ability to guide the students through the development of peer interactions within the classroom [30]. In addition, the teacher should know how to manage student group dynamics for optimization of the group work [31], such as having a reduced number of members or monitoring the work of each student [32]. An intra-group formative evaluation is the most effective alternative, because peer opinions on the classroom work can be more highly valued among students than the evaluation of the teacher [32].

Within the engineering field, FACW is a very innovative teaching approach for engineering careers [33] that favors the development of the necessary professional skills, through a cooperative framework between peers for the resolution of practical approaches and critical peer reflection at work [31]. The evaluation between peers (co-evaluation), with the necessary objectivity, can foster better follow-up of student learning processes, while promoting personal responsibility for peer evaluation of work assignments [18,34], a highly beneficial aspect for adaptation to professional working life. A balance between the concepts that the teacher wishes to transmit to the students and the development of their own personal skills can be achieved with FACW [35].

In the context of the present study, student perceptions of a technical study module—Structures II—that incorporated a FACW experience for the first time, are evaluated. The study module formed part of the Degree in Mechanical Engineering of the University of Burgos, Spain. Both the perceived usefulness of this type of teaching experience among students and their attitudes towards the teaching modality that they considered most appropriate for their learning processes were evaluated. As the students themselves confessed, since this type of teaching experience on such a specific technical subject was new to them, conclusions relating to existing shortcomings in their own learning processes could be analyzed. They were therefore invited to draw conclusions from a multi-competent point of view, including not only the technical concepts to be acquired, but also other skills such as teamwork and autonomous critical thinking. The areas where FACW might have brought the greatest benefits could therefore be identified, upon which the teaching work should focus when applying this methodology to these sorts of subjects.

2. Materials and Methods

The approach of the FACW experience and the type of analysis that was performed is described below.

2.1. Class Context

The FACW experience took place during the practical classes of the Structures II study module, taught in the fourth year of the Degree in Mechanical Engineering of the University of Burgos, Spain. The main objective of this 4-year degree course is to train professionals in industrial engineering, with a specialization in mechanization and machine operations. However, a general training is also imparted on this degree, so that students, upon completion, will have acquired competences for their adaptation to any type of technical work that is required in both engineering companies and industries, as well as access to a large number of specialized Masters of Science courses in the engineering field. The main objective of Structures II is for the student to learn the theoretical rules for dimensioning reinforced concrete structures. In this way, student learning is not excessively focused on the purely mechanical field. After refreshing student knowledge of the calculation of internal forces seen in previous courses, dimensioning and reactions to flexural and shear forces are covered in the module, as well as the verification of service requirements, such as cracking and deformation. Following these classes, students should be able to design simple beams and columns. The dimensioning of rigid footings, the simplest foundation on which a structure can be supported on the ground, is covered in the final weeks. According to the teaching guide, the study module also calls for the development of critical reasoning, interpersonal and teamwork skills, and ethical responsibility in the exercise of the profession.

Various different reasons explain the choice of this study module for the FACW experience:

- Firstly, because structural design is a technical subject in which complex and extensive calculations are required, where each practical class is very frequently dedicated to solving a single problem in a complete and detailed way. Time constraints may be one reason why FACW is not a very widespread teaching modality.
- As a final year subject, students have gained a global and critical vision of the type of teaching used in this kind of subjects.

The choice of the practical classes on rigid footings and their calculation was because of the shorter length of the exercises and their position in the curriculum at the end of the subject module, when the students had already gained an autonomous working knowledge of the subject-related concepts. The practices took place in a large classroom, equipped with a double blackboard and projector, with a capacity for approximately 100 students. Although not arranged for group work, the classroom environment was successfully adapted to group work by moving the furniture.

2.2. Participants

The participation in the experience was 94.2%, as 52 students enrolled in the study module, from among whom 49 (n = 49) participated. From the total sample, 89.8% were men (44 men and 5 women), 10.2% were second-registration repeaters (4 men and 1 woman), and 2.0% were third-registration repeaters (1 man). The average age of all the participants was 22.64 ± 1.96 years (22.78 ± 2.02 years for men, and 21.48 ± 0.36 years for women). The average age of the repeaters was 25.50 ± 3.58 years. At the beginning of the FACW experience, all of them confirmed that they had never participated in such an activity in this type of study module.

2.3. Experiment Design

The experience consisted of the cooperative solution of an exercise concerning the design of a rigid footing. The solutions that the students advanced were evaluated in a formative manner through classroom debates. During the corresponding theoretical classes, both the theoretical and methodological concepts necessary for arriving at a solution to this exercise had been formally presented in the classroom.

The participants were divided into ten groups, all with five members, except for one group of four, which were freely formed by the students. Group formation was not guided by the teacher, so the tendency among the students was to form groups based on friendship. Pre-existing relations based on trust and friendship favored fluid communication between group members. There was however a suspicion that was assumed: Some groups would not function in an optimal way as a result of their tendency to be distracted, due to the existing friendships between its members [36]. The students also designated a spokesperson for the group. Each group member was assigned a number from 1 to 5, for the application of the "numbered heads together" methodology, a teaching method in which the students work in groups while solving a problem within a given time. At the end of that time, a number is chosen at random and each group member with that previously assigned number must present the agreed solution to the rest of the class. In this way, all the members of the group must be concerned with understanding the solution to the problem, because everyone must be able to explain the solution of the problem when the time is up [37].

Subsequently, the exercise and four stages for its completion were proposed: Calculation of design forces, determination of the footing dimensions, and dimensioning and calculation of the reinforcements in both the longitudinal and the transversal directions. The groups completed the exercise in stages, referring to their course notes. They worked autonomously with sufficient time to complete each stage and for all of the groups to reach a solution, with the teacher available to solve the doubts raised by the groups through the spokesperson. At the end of every stage, all the group members should be able to explain the solution to the rest of the class.

Having completed each stage, a number was chosen at random, so that each student from each group to whom this number had been assigned could briefly present their group solution on the blackboard. After these presentations, an inter-group discussion was prompted with the active participation of the teacher on the strong and weak points of each solution. During this debate, the students from the different groups, through their spokesperson, presented their opinions on these successes and/or errors. The same process was repeated for each of the four stages, and then the students were given the solution to the exercise and asked to answer two questions individually. Their answers to these questions were completed with group support with the spokesperson stimulating debate and critical reflection within the group. The teacher also responded to both questions, adding different points of view to the analysis, as well as referring to the obstacles and the aspects that could be improved in the future.

2.4. Tool

The perceptions of the students during this experiment were collected, as explained above, through two blocks of open questions linked to the usefulness of FACW compared to the traditional teaching based on formal presentations of technical subjects and the type of teaching considered most appropriate for learning. The analysis of the responses constituted the central objective of the present study. The two blocks of questions were:

1. What have you gained from the cooperative work and formative assessment developed in this class? Are there any aspects that you would like to highlight? Why?
2. Which teaching method do you consider most appropriate for these types of technical subjects: The traditional method based on formal presentations or the one experienced today? Please give a reasoned answer.

Progressive reflection followed on these two questions: First, the classroom experience was evaluated, and then it was extended to the whole set of subjects of the same typology.

Students were asked to indicate their profile when responding (male or female, repeater or not) in order to establish relationships between the responses and the student profiles, thereby ensuring the anonymity and confidentiality of the participants.

2.5. Analysis Methodology

Once collected, the information underwent two types of analysis, one qualitative and one mixed, using ATLAS.ti (version 8) [38]. In these two types of analysis, the information was divided into categories, which were coded according to the profile of each member of the sample.

- On the one hand, qualitative analysis was used to gain an accurate understanding of student perceptions, so as to gain greater insight into their learning-related processes [39]. This methodology was intended to answer questions arising from such a specific context [40], thereby obtaining a wide vision of the positive and negative aspects detected by the students.
- On the other hand, the mixed analysis that looked at words and co-occurrences of codes generalized and extracted a global vision of the perspectives that the students had expressed, establishing a stratification between the different aspects detected and the relations between them [41].

In addition, a statistical analysis of the relations of dependency between the aspects addressed by the students was also performed, using Statgraphics software (version 18) [42], with the aim of confirming the overall conclusions reached with the mixed analysis.

3. Results

The results obtained from the three types of analysis preformed were as follows.

3.1. Qualitative Analysis

The qualitative analysis was conducted through a theme-based content analysis and continuous comparison. The different text fragments were coded in two levels using cross patterns. The first level of coding was gender and whether the student was a repeater or not: NRM (non-repeating man), NRW (non-repeating woman), RM (repeating man), RW (repeating woman), and T (teacher). The second level of coding was defined according to the aspect addressed by the students in their answers: Personal opinion related to FACW methodology, classmates' attitudes, deficiencies detected, and preference regarding the teaching methodology. The authors of this article worked through continuous feedback, which allowed for an exhaustive analysis of all the transcripts. In total, 252 text extracts were analyzed, with an average length of 50 words.

Through the explained coding and analysis, the salient aspects in relation to each category were indicated, as well as the most significant text extracts. The response of the teacher to these questions was also analyzed, as well as the obstacles and possible future improvements for this type of teaching experience.

3.1.1. Usefulness of the Educational Experience Developed

The 109 text extracts under analysis showed a general acceptance of the experience developed by the students (positive evaluation of 42 of the 49 participants). All negative evaluations corresponded to NRM, which showed a preference for more passive learning methodologies. There were also some complaints about the way in which group members worked.

> "[...] I prefer to copy the solution, go home and concentrate on trying to understand all the concepts [...]" "[...] I don't see the advantage of debating among ourselves if something is right or wrong [...]" "[...] My group was mainly concerned with copying some other group [...]" (NRM)

In spite of the existence of some negative evaluation among the NRM collective, they stressed the support received by some companions as a great advantage of the experience. They also stressed that the students with greater knowledge made an effort to help others understand the concepts. They recognized that peers could be a support point to achieve better learning and thus a better grade. The debates held at the end of each stage were also positively valued, in so far as the students recognized that it facilitated the sharing of doubts, and they highlighted the work of the spokesperson as an advocate for the opinion of the whole group. An active and open attitude of the teacher towards discussing any issue during the class was also positively assessed.

> "I was surprised my classmates knew so much about the subject. I would never have thought of asking them all my doubts [...]" "[...] I would highlight that the problem solution is easily reached when I think with other classmates." "I liked being able to be a spokesperson. I felt that I was defending the opinions of my classmates and we formed a united group [...]" "[...] I liked explaining my opinion to others [...]" "I think the debates were the key. A classmate correcting you is not as embarrassing as the teacher doing it [...]" "[...] The teacher has listened to us and has valued our contributions [...]" "[...] the teacher has shown a positive attitude and a lot of patience [...]" (NRM)

The non-repeating women, NRW, not only highlighted group members, but the group as a whole, emphasizing the unity within it to move in the right direction, thereby presenting a more collective mentality in their reflection. Furthermore, they highlighted both inter-group and intra-group discussions, the latter often leading to the right solution.

> "The support from the group has been incredible. Each member knew something different [...]" "[...] The collaborative spirit of the group has been very good." "[...] I also liked the internal discussion within the group, with each person giving their point of view [...]" "[...] I loved the group discussion that replicated some of the statements made by the teacher and other classmates [...]" "[...] All the members of the group have gone in the same direction to solve things." (NRW)

The repeaters, RM and RW, regardless of gender, highlighted that the explanation through this methodology was of greater simplicity, with less technical language, and they also highlighted the significant assistance of their peers to pass the subject, which they had not found easy. Its novelty was also stressed, which prompted greater interest during the class.

> "All the concepts and ideas were explained in a simple and less technical way, due to the participation of the students [...]" "[...] the explanation was simpler and more accessible [...]" "[...] Last year I was quite lost and it has not improved this year, but perhaps with this type of work, where I find support from my classmates, it would have been easier for me." "[...] It has broken the monotony, classes were always the same every year [...]" (RM, RW)

The teacher, T, also valued the experience positively, emphasizing the high levels of class participation and the quality of inter-group criticism. In general, the teacher considered that the intra-group work was correct, with the exception of one group that functioned poorly. The members of that group fundamentally considered the experience as a game, rather than a different form of learning, paying insufficient attention, and talking and telling jokes amongst themselves. For this reason, the professor considered that a careful selection of the members of each group was necessary to ensure that the work could go ahead correctly, without disruptive behavior. In his opinion, this behavior could be favored by the promotion of passive forms of teaching, in which autonomous student work is not necessary, and the classes are not considered a fundamental element of learning, nor the classwork is graded. In this way, the subsequent study of the personal class notes and even those from other colleagues, is sufficient to promote a learning process.

> "[...] I was surprised by the high participation in the discussions, all the groups were very active. Once they've lost their initial fear of speaking, they dare to reply to their peers and even to the appreciations that I made, generally referring with great precision to concepts and ideas [...] The work in the groups went well [...] except in one group, which did not reflect any interest [...]. It showed a passive attitude, perhaps due to a habit of being taught in formal classes [...]" (T)

3.1.2. Teaching Modality Considered Most Suitable for Learning

The 143 text extracts under study showed a clear correlation with the answers to the other question, as those students who were unable to associate any advantages with FACW showed a clear preference for formal classroom presentations. These opinions were motivated by preferences for a more passive attitude and poor acceptance of peer criticism and correction, considering that they should not correct their mistakes.

> "I find it easier to copy the solution written by the professor on the blackboard [...]" "I prefer the traditional class [...] I have to put up with my classmates saying that there are things I do wrong [...]" (NRM)

Among the first-registration students in favor of this type of teaching, opinions were practically uniform, regardless of gender: In this type of subject, where the understanding of theoretical concepts is fundamental to understand the practical part, a mixture of both teaching modalities is necessary: Formal presentations, for the explanation of the theory, and practical classes. The students mainly stressed the usefulness of FACW for the practical part, although they thought that the theory would be best explained by the teacher through formal presentations. Some recognized that their understanding of the theoretical concepts could be improved during the discussion phase of the practical part, thereby reducing the time dedicated to formal presentations. They thought that the role of the teacher was fundamental to the success of the FACW, explaining the theory and guiding the discussions in the right direction.

> "I think that in this kind of subject you have to find a balance. There are many concepts to understand, in order to approach the exercises with sufficient knowledge and these must be explained as always [...]" "[...] Without the theory class nobody would've been able to solve anything" "[...] At the beginning of each subject to be dealt with, the teacher must explain the key ideas to be taken into account [...]" "[...] The concepts must be explained in the theory class, perhaps in a shorter way than is usually done [...]" "[...] The professor explains the theory and the practical parts are solved in a group, with the help of the professor [...]" "[...] I would not let the students explain the concepts to each other, the professor should be the moderator and guide the debate [...]" (NRM, NRW)

Repeating students, regardless of gender, preferred FACW methodology. They indicated that the class was more enjoyable and participatory with FACW, as it stimulated and maintained their interest in the subject, so much so that it appeared to be less repetitive than the preceding year.

> "[...] It has made me more attentive [...]" "[...] It has made me much more interested in the class and clearer about the issues seen today. [...]" "[...] Perhaps, in this way, the subject has become less repetitive since we studied the same material last year." (RM, RW)

As the experience developed, the teacher also expressed a preference for the FACW, fundamentally referring to the high levels of participation to explain his opinion. However, he also expressed caution over the best way to approach the explanation of theoretical concepts. In his opinion, the theory could not be cooperatively approached in such a simple way. He indicated the need to achieve a balance between formal theoretical presentations and the FACW for this type of subject, proposing a reduction in the time dedicated to theoretical explanations and its intercalation with periodic discussion.

> "I am in favor of teaching more through this methodology [...] the theoretical concepts are generally basic to address the resolution of the practical issues, they cannot be treated, as in other subjects, as two completely different elements [...] We must find a way to combine both methodologies, perhaps by shortening the formal presentations or intercalating teaching during the periods of discussion [...]". (T)

3.1.3. Obstacles Encountered and Possible Future Improvements

The professor expressed a very favorable opinion towards the FAWC experience, despite the greater personal work that was required to ensure, from his point of view, that all the stages in the resolution of the exercise could be successfully addressed by the students. However, in his opinion, this greater previous work was compensated by the lesser effort required during the development of the class and by two aspects of student behavior: Higher levels of student participation, achieving a much more dynamic and enjoyable class, and the clear attitude of solidarity between students, so much so that the students with difficulties felt supported by some of their classmates. Although the students initially found themselves a little out of place, unclear over their roles, some guidelines on the working practice resolved this initial problem.

The teacher highlighted two main areas for improvement. Firstly, group formation should follow a mixed procedure, with an initial selection by the students, and then the teacher should have the chance to change some students, on the basis of their past classroom behavior. The purpose of placing students would be to achieve group synergy, so that group work would be beneficial to all its members. This aspect has been also found in other studies [32]. Secondly, adjustments to the time spent on theoretical explanation could potentially add extra time to group work. The teacher indicated that, in this way, more time could be reserved for the debates, in which the doubts and questions were, in his opinion, of immense interest. As the questions were raised, the students progressively showed a greater tendency to speak, explaining their points of view to others.

3.2. Mixed Analysis by Words

First, a word-by-word analysis of the answers given by the students to each of the questions was carried out. The same first-level coding was used as in the qualitative analysis. This analysis had the purpose of generalizing student perceptions of FACW.

3.2.1. Usefulness of the Educational Experience Developed

As shown in Table 1, NRM mostly referred to the importance of individual peers, with only 20% considering that the support of the whole class (all groups together) had been a fundamental instrument in learning. On the contrary, 100% of NRW considered that the group was the most important entity, highlighting its members in a general way, without individualizing the work through references to peers. This idea of unity was also repeated among RM and RW, as their previous negative experience of the subject meant that they valued the support from the whole class very positively. The work of the teacher, as the presenter of the concepts and the moderator of the discussion phases was considered necessary by 37.5% of NRM, although less so among NRW. However, the word "subject" shed light on a concept that had not been detected through the qualitative analysis: The students conceptualized the subject in global terms, yet as the experience was a discrete intervention, and they considered that it would have a very scant influence on the development of the subject module and, therefore, on their learning processes.

Table 1. Most frequent words in the first question. NRM: Non-repeating man; NRW: Non-repeating woman; RM: Repeating man; RW: Repeating woman.

NRM			NRW			RM and RW		
Word	Absolute Frequency	Relative Frequency (%)	Word	Absolute Frequency	Relative Frequency (%)	Word	Absolute Frequency	Relative Frequency (%)
Classmate(s)	17	42.5	Group(s)	6	150	Classmate(s)	6	120
Group(s)	16	40.0	All	4	100	Class	4	80
Teacher	15	37.5	Debate(s)	3	75	Support	4	80
Debate(s)	10	25.0	Solve	3	75	All	4	80
Subject	9	22.5	Achieved	2	50	Subject	3	60
Class	8	20.0						

3.2.2. Teaching Modality Considered Most Suitable for Learning

Two aspects of great relevance, which had already arisen in the qualitative analysis, were detected in the perceptions of the students through the content analysis of the responses to the second question (Table 2): The relevance of the role of the teacher as a guide to the subject, and student opinions on the approach to the completely differentiated treatment of the theoretical and the practical parts, supporting mixed teaching between the traditional (formal presentations) and both the formative and the cooperative approaches. A large number of students linked the quality of teaching to this balance between both teaching typologies. Unlike the first-registration students, the repeaters gave priority to the support they received from their classmates when opting for FACW.

Table 2. Most frequent words in the second question.

NRM and NRW			RM and RW		
Word	Absolute Frequency	Relative Frequency (%)	Word	Absolute Frequency	Relative Frequency (%)
Teacher	32	72.7	Class	3	60.0
Type(s)	22	50.0	Classmate(s)	3	60.0
Exercise(s)	18	40.9	Support	3	60.0
Teaching	16	36.4	Exercise(s)	2	40.0
Both	15	34.1	Subject	2	40.0
Theory	10	22.7			
Concept(s)	8	18.2			
Traditional	7	15.9			
Subject	4	9.1			

3.2.3. Global Analysis. Definition of Coding for Mixed Analysis by Co-Occurrences

The most repeated words obtained through the joint analysis of all students to both questions (Table 3) showed the same trends as the individualized analysis for each question and population group, which were taken as the basis for coding in the crossed analysis (co-occurrences). Among the codes that were used, the term "classmate(s)" referred to students who were part of a "group", while all the groups together constituted the "class". The term "teaching" referred to the quality with which it was imparted, while the term "both" encompassed both formal presentations and cooperative teaching when the students considered both essential. The other terms ("teacher", "support", "exercise(s)", "debate(s)", and "theory") retained their traditional meanings.

Table 3. Base words for coding in mixed analysis by co-occurrences.

Word	Frequency
Teacher	49
Class	41
Classmate(s)	38
Group(s)	30
Support	21
Teaching	19
Exercise(s)	18
Both	15
Debate(s)	13
Theory	13

3.3. Mixed Analysis by Co-Occurrences

The analysis of co-occurrences was used to evaluate the simultaneity with which the students referred to the different aspects, identifying symbiosis and unions of concepts. This analysis was carried out for each of the two issues under study. The coding (see Section 3.2.3) was not a reflection of the fact that the words were mentioned or not, but referred to the meaning of the sentences. Analyzed text extracts in the qualitative analysis were joined, so the number of extracts used in the mixed analysis was lower.

3.3.1. Usefulness of the Educational Experience Developed

The table of co-occurrences (Figure 1) for the question related to the usefulness of the educational experience performed showed several relevant aspects:

- The concepts of classmates and groups were not addressed together in the students' responses. Although the group work was valued positively, many students referred to the support of individual peers within the group, not the group as a whole. In only 26.7% of the times was the concept of peer used to refer to the whole group, mainly among NRW.
- The debates were positive, but the role of the teacher was considered fundamental on 70% of occasions, while the role of the other groups was not seen as relevant. Among the students who considered the teacher's role as relevant, 33.3% indicated its usefulness during the teamwork phases, supporting the students during the resolution.
- There was little connection between the discussions and the class, which were mainly seen as interaction between the teacher and the classmates or between the teacher and the group, without in general valuing the discussion with other groups as a beneficial learning element.

	Support (26)	Class (10)	Classmate(s) (30)	Debate(s) (10)	Exercise(s) (6)	Group(s) (20)	Teacher (18)
Support (26)		7	16	3	4	11	6
Class (10)	7		7	3		2	2
Classmate(s) (30)	16	7		5	3	8	9
Debate(s) (10)	3	3	5		1	3	7
Exercise(s) (6)	4		3	1		4	2
Group(s) (20)	11	2	8	3	4		5
Teacher (18)	6	2	9	7	2	5	

Figure 1. Number of co-occurrences for the first question (times that each pair of concepts are jointly mentioned, in the students' answers).

3.3.2. Teaching Modality Considered Most Suitable for Learning

The table of co-occurrences for the question related to the most appropriate teaching modality in technical subjects (Figure 2) showed that:

- Out of the 34 times that the answers of the students addressed the work of the teacher, on 30 occasions it was linked to the explanation of the theoretical concepts, also highlighting the high levels of concern in relation to theoretical concepts and their doubts over the way to approach it through a FACW methodology.
- 95% of the students considered that theoretical material should be formally presented in the classroom and opted for a combination of teaching modalities: Formal presentations to explain the theory and FACW for the applied practices.
- Only 22.4% of the students reflected upon the quality of teaching in their answers, and when doing so, linked it fundamentally to the work of the teacher and proper theoretical explanations. These reflections on the quality of teaching were not linked, for the most part, to proper group work, nor to a need for quality debates. While the debates were an element highlighted in the first question, referring to the usefulness of the experience, the students never considered it a relevant aspect when deciding on the most appropriate type of teaching, leaving it in the background.

	Both (20)	Support (22)	Class (7)	Classmate(s) (12)	Debate(s) (6)	Teaching (11)	Exercise(s) (5)	Group(s) (13)	Teacher (37)	Theory (34)
Both (20)		8	2	1	4	3	4	7	20	19
Support (22)	8		5	10	4	5	2	8	17	11
Class (7)	2	5		2	1		2		7	3
Classmate(s) (12)	1	10	2			3		1	6	4
Debate(s) (6)	4	4	1			1	1	5	6	4
Teaching (11)	3	5		3	1			4	8	9
Exercise(s) (5)	4	2	2		1			1	5	5
Group(s) (13)	7	8		1	5	4	1		10	8
Teacher (37)	20	17	7	6	6	8	5	10		30
Theory (34)	19	11	3	4	4	9	5	8	30	

Figure 2. Number of co-occurrences for the second question (times that each pair of concepts are jointly mentioned, in the students' answers).

3.3.3. Global Analysis

The analysis of the global co-occurrences (Figure 3) allows us to summarize all the aspects observed, following the general scheme represented in the conceptual network of Figure 4. It highlights that, although FACW requires high levels of participation among classmates, groups, and class, most global references were made to the teacher, reflecting the importance of that role in all the aspects: Quality teaching, explanation of the theory, support to the groups (intra-group discussions), and guide to the inter-group discussions. Overall, the students mainly referred to support from individual peers, and they neither related the concept of classmate to that of group and class, nor was quality teaching linked to the joint work of all the groups within the class.

	Both (20)	Support (48)	Class (17)	Classmate(s) (42)	Debate(s) (16)	Teaching (11)	Exercise(s) (11)	Group(s) (33)	Teacher (55)	Theory (34)
Both (20)		8	2	1	4	3	4	7	20	19
Support (48)	8		12	26	7	5	6	19	23	11
Class (17)	2	12		9	4		2	2	9	3
Classmate(s) (42)	1	26	9		5	3	3	9	15	4
Debate(s) (16)	4	7	4	5		1	2	8	13	4
Teaching (11)	3	5		3	1			4	8	9
Exercise(s) (11)	4	6	2	3	2			5	7	5
Group(s) (33)	7	19	2	9	8	4	5		15	8
Teacher (55)	20	23	9	15	13	8	7	15		30
Theory (34)	19	11	3	4	4	9	5	8	30	

Figure 3. Number of co-occurrences for questions 1 and 2 (times that each pair of concepts are jointly mentioned, in the students' answers).

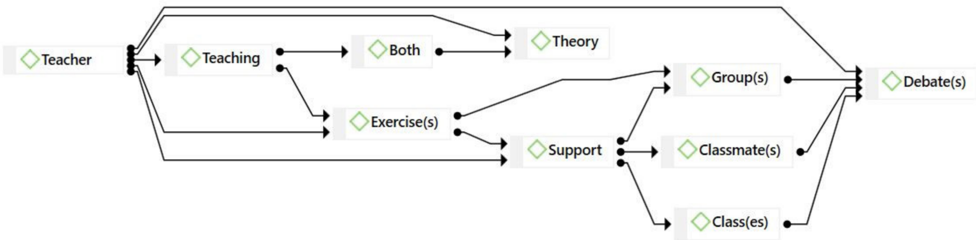

Figure 4. Conceptual network that summarizes the student's perceptions.

3.4. Statistical Analysis

The global analysis was completed with a statistical approach to evaluate the dependencies between the concepts mentioned by the students at a significance level of 5%. Ten qualitative variables were defined, which coincided with the codes used in the mixed analysis by co-occurrences (see Table 3) and which adopted the value "yes" or "no" for each student and each question, depending on whether or not that concept was addressed in their answer. The chi-square test was performed on the different pairs of variables, the *p*-values for which are shown in Figure 5. The null hypothesis of the test was the independence of the variables, which must be rejected when the *p*-value is lower than the level of significance under consideration. Figure 5 also highlights the *p*-values lower than 0.05 in yellow, which show those pairs of variables for which the null hypothesis must be rejected, as there is a relation of dependency between the variables involved in its calculation.

	Both (20)	Support (48)	Class (17)	Classmate(s) (42)	Debate(s) (16)	Teaching (11)	Exercise(s) (11)	Group(s) (33)	Teacher (55)	Theory (34)
Both (20)		0.2383	0.2759	0.0001	0.3076	0.0364	0.2082	0.5750	0.0001	0.0002
Support (48)	0.2383		0.0143	0.0108	0.2941	0.7765	0.0072	0.0349	0.0325	0.0765
Class (17)	0.2759	0.0143		0.3770	0.0389	0.1044	0.9515	0.0598	0.7305	0.0977
Classmate(s) (42)	0.0001	0.0108	0.3770		0.0278	0.2546	0.2546	0.2345	0.3566	0.3465
Debate(s) (16)	0.3076	0.2941	0.0389	0.0278		0.4822	0.0478	0.0133	0.0301	0.3565
Teaching (11)	0.0364	0.7765	0.1044	0.2546	0.4822		0.0207	0.8005	0.0416	0.0006
Exercise(s) (11)	0.2082	0.0072	0.9515	0.2546	0.0478	0.0207		0.0350	0.6220	0.4425
Group(s) (33)	0.5750	0.0349	0.0598	0.2345	0.0133	0.8005	0.0350		0.1706	0.1454
Teacher (55)	0.0001	0.0325	0.7305	0.3566	0.0301	0.0416	0.6220	0.1706		0.0001
Theory (34)	0.0002	0.0765	0.0977	0.3465	0.3565	0.0006	0.4425	0.1454	0.0001	

Figure 5. *p*-values for the chi-square test of each pair of variables.

This analysis showed the same aspects that were also detected through the mixed analysis. On the one hand, the concept of teacher is related (dependent variables) to both teaching methodologies (formal presentations and FACW), support to students, debates, teaching quality, and the explanation of theoretical concepts. On the other hand, the explanation of theory is closely associated with the quality of teaching, which shows the relevance that the explanation of theoretical concepts has in a technical engineering course. The concepts of "classmate", "group", and "class" are important, in the opinions of the students, in the formative debates and the support to solve the exercise, but no relation is maintained between the independent variables: Students do not need the global support of the whole class or the group (set of classmates) during the resolution of the exercise, but they consider that the support of some individual classmates is sufficient in itself.

4. Discussion

The results reflected very relevant aspects related to the perceptions among students of a FACW experience for a highly technical subject, in which the concepts, once theoretically explained, are fundamental for properly learning and understanding the practical part. Although the students were in favor of learning based on group work and peer support, they made it clear that the role of the teacher continued to be fundamental, both in relation to explaining theory and in supporting groups and the class during the cooperative phases and discussions.

This consideration of the teacher's role as fundamental is motivated by the great predominance of the formal presentations in these type of technical subjects, in which the teacher takes charge of transmitting the knowledge and defining the requirements for passing, rather than attributing importance during the learning process to formative and cooperative processes within the classroom [11]. The fact that the students had never received this type of training in any technical subject, although FACW streams have become more frequent in recent years [43], means that they neither considered the class as a whole nor the formative discussions as a fundamental element in the development of their learning. The repeaters were an exception, as their previous negative experience in the subject led them to value cooperative learning and peer support much more than the other students.

It can therefore be stated in relation to these technical subjects, that students need to experience learning at a personal level. This learning experience is related to the benefits of the class as a whole and that the other groups can provide through co-evaluations and formative debates, exchanging different viewpoints, and explaining concepts that are not properly understood within the group in simple ways, fostering optimal learning of very specific course content. Students must be able to give their opinions and make mistakes when following this process, and therefore these processes should not be reflected in the assessment of the subject, but should be understood as a process of formative evaluation, the only objective of which is that each student is supported and assisted within a peer group, favoring joint learning [44,45]. Examinations will in any case be able to continue to be the main source of assessment and it may be assumed that the validity of FACW experiences could be analyzed through the results [46].

Personal learning must be accompanied by an increase in autonomy in this process, so that the role of the professor is not considered so relevant and students feel able to make objective judgements on the different theoretical and practical concepts studied in the subject [47]. The progressive nature of the technical subjects demands a thorough understanding of the concepts taught in previous lessons, so that the students can confront the new aspects of each session. It means that exercises will be solved through the creation and progressive resolution of successive tasks that refer to the theoretical content of previous sessions, already familiar to the student. Such an approach will favor this autonomy, motivating the students and providing them with different challenges within the same class that will lead to greater involvement. Coordination between different technical subjects in the same field, which is currently very scarce, could also favor cross learning, with a better relationship between the different concepts [48] and could even lead to higher class attendance and more active participation [19]. The development of positive attitudes towards the application in the future profession of the concepts seen in the subject will not only favor greater autonomy and interest on the part of the student, but also an overall perception of the training received in all technical subjects [49]. It will also enable the development of teamwork skills that are fundamental to many professional aspects of engineering [50].

Throughout this context, it is essential to link training to the social and cultural reality of society, emphasizing elements of great social relevance today. Within the field of engineering, in which many technical subjects are framed, the fundamental role of engineering in achieving an optimal relationship between humankind and nature stands out [51,52]. The teacher should reflect on the objectives pursued in the classes [53] and will inevitably continue to play a fundamental role, above all with regard to the orientation of the subject and the competencies that the students must acquire in relation to the different aspects that have been discussed. Nevertheless, autonomous work and less learning-related teacher dependence must be promoted through the horizontal organization of classroom groups, so that all their members actively participate in the understanding of the concepts [18]. The development of this learning autonomy must be accompanied by the development of what can be called teaching autonomy, so that each student, moved by a feeling of solidarity and belonging to the class, can explain the concepts that have been learned to any classmate, not only to other group members. Within this situation, the vertical organization of the groups by means of the designation of a spokesperson and the promotion of the leadership is fundamental for an optimal development of this methodology, favoring the proper organization of each session [54].

The current reality of these types of subjects also has an impact on student perceptions of the most appropriate teaching modality, reflecting a clear preference for explaining theoretical concepts through formal presentations. Despite the fact that it is common for students starting out in FACW to show greater insecurity when faced with this type of teaching [55], careful delimitation of the evaluation procedures, which should not be related to the formative and cooperative activities developed during the class [56], proper regulation of the work [57], continuous work programs, and the development of strategies to deepen previously acquired knowledge [15] are all effective measures that can alter this perception and promote student autonomy. It is essential that the change of perception should be based on the three above-mentioned aspects, rather than its mere reduction to the requirement to pass the subject, an element that fundamentally conditions a students' vision of the subject [54]. The shared use by both students and teacher of activity assessment scales during cooperative classes, similar to those used for the definition of the subject's grade, may favor this adaptation [15]. Nevertheless, the methodology of formal presentations, in relation to this type of subject, will continue to play a fundamental role in gaining a complete understanding of the theoretical base necessary to approach the practical procedures. The teacher has the most knowledge of these aspects and can convey them in greater depth to the students, although active participation among students through practical exercises that are cooperatively approached and through questions for group discussion must be favored during the development of the class [58].

All the aspects commented in this discussion have been obtained from the initial experiences of the students with the application of the FACW methodology in a technical subject. The conclusions obtained are relevant to assess the advantages that this teaching methodology could provide and the aspects to consider in its implementation. However, as this was a one-off experience, these observations would need a practical validation over time through monitoring the evolution of student learning, in relation to both the technical concepts and the skills of autonomy and group work.

5. Conclusions

This study has sought to assess the perceptions of students participating for the first time in a formative and cooperative assessment experience involving highly technical and specialized subject matter. The evaluation concerned: (1) The usefulness that the students detected in this teaching modality; and (2) the preferred teaching modality for this type of subject.

In relation to the first aspect under evaluation, it is clear that the students considered that peer or peer-group support was a very valuable element for satisfactory resolution of the practical aspects. The formative debates, in which the students corrected each other, were likewise relevant for optimal learning. However, they did not consider the whole class as a fundamental element for optimal learning, referring mainly to the support of individual peers within their own group. Regarding the second question, the students showed a positive attitude towards this type of teaching with respect to the practical aspects of the subject, although they showed an unfavorable opinion towards a complete adoption of this teaching methodology, indicating their preference for formal presentations of the theoretical content. This opinion was also shared by the teacher, who also argued in favor of greater student participation in both theoretical and practical activities.

The absence of cooperative teaching in highly complex subjects and an intimate relationship between theory and practice has meant that individual work and the consideration of the teacher, as the only link between the different concepts to be learned, has traditionally been encouraged. The students in this study showed no signs of considering autonomy as a necessary element for proper learning processes. They considered the support of a few classmates or members of their group to be sufficient, rather than that of the whole class. Nor was peer discussion considered as a relevant element in the quality of the teaching that is imparted. However, the students did consider that support from the teacher was fundamental, both in the debates and in the phases of teamwork and, above all, in the explanation of the theory.

This study is especially directed at teachers of highly specialized technical subjects, in which both theoretical and practical concepts are so inextricably linked that they cannot be treated as individual elements. It has been observed that the application of formative assessment and cooperative work to these subjects can promote autonomy and inter-group communication, so that the teacher is considered as a guide to knowledge acquisition and not as the person upon whom the learning process is dependent. Such an approach also means that the student can consider all fellow students as peers providing support and motivation throughout the learning process. In the light of these aspects, almost any course subject could be adapted for the incorporation of the formative assessment and cooperative work teaching modality and, in this way, promote the skills that are fundamental for the professional sphere.

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