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Cooperative and Collaborative Learning: An Innovation in Teaching Medical Physiology

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Abstract

The implementation of didactic methodologies in medical physiology courses supports the improvement of students' physiological and critical thinking. The objective of this study was to analyze the educational experience in the physiology course of the medical program in a higher education institution in southern Colombia during the academic periods taking place between 2018 and 2019. It was carried out with an exploratory sequential mixed-methods approach, which was carried out in four phases based on C. Chadwick's Instruction model. Activities based on collaborative and cooperative learning were designed and applied through a learning guide and the results were evaluated through focus groups. Learning styles were also assessed to see if they were associated in any way with academic success. A total of 204 medical students participated, of whom 36% were male and 64% female. Their average age was 19.5 (SD ±2.7) years, and their learning styles were assessed by means of the Herrmann Brain Dominance Instrument. 32.4% of the males and 22% of the females were assessed as having a left-cerebral learning style, while 18% of the males and 20% of the females were assessed as having a combined left-cerebral and left limbic style. Additionally, the results of academic performance were analyzed according to sex and age. In the qualitative analysis. The most relevant pedagogical-didactic category identified was the contribution of collaborative work to successful learning during the physiology course, as participation in it led to significant learning by physiology students. Collaborative and cooperative learning allowed the topics to be learnt through student interaction, thereby promoting teamwork.

Keywords: *Medical Physiology; Critical Thinking; Physiological Thinking; Cooperative Learning; Collaborative Learning*

1. Introduction

Physiology is a fundamental part of the curricula of health sciences, animal health, physical education and sports education programs, among others. Healthcare programs dedicate between four and eight academic credits to learning physiology, where students study the dynamic equilibrium of life and physiological adaptations that seek to achieve homeostasis (Harold Modell, 2015). Physiology is a discipline which requires mathematical, analytical and critical skills. Many students base their learning on memory, which makes it difficult to develop critical thinking, a skill that aids decision making and the prediction of physiological adaptations (Breathnach, 2013), (Bernard, 1879), (Michael J. , 2007), (Caroline Altermann, 2016), (Dobson, 2009). *Michael J.* described the high degree of difficulty in learning physiology, related to three main aspects: the nature of the discipline, the way of teaching and the approach and/or study techniques used by students. These three factors make learning superficial in many cases (Michael J. A., 1998). Therefore, in order to achieve meaningful learning, the student must be motivated to assimilate the concepts and their application; that is, they must carry out metacognitive processes (Schunk, 1994). However, these processes depend on emotional and cognitive conditions as explained by *Ausubel,* (Ausubel, 1978).

Traditionally, physiology courses are offered face-to-face with methodologies that are framed in directed or guided learning. In recent decades, some programs have included methodological strategies based on the constructivist approach, such as problem-based learning (PBL) framed in collaborative learning, which began in 1960 with training in collaborative learning at the University of Minnesota given by brothers *David* and *Roger Johnson* (Johnson, 2018). Collaborative learning is a method that uses social interaction as a way to construct knowledge, and which requires students to work in groups of two or more to achieve a common goal, respecting the contribution of each member of the group; whereas collaborative learning is related to working or acting as a group to achieve a common goal, which tends to reduce the importance of the contributions of the individual group members (Andreu Andrés, 2016). They started the Center for Cooperative Learning with the aim of improving knowledge integration, modeling theories on cooperative learning and collaboration, while conducting educational research. In 1970, Professors *David DeVries* and *Keith Edwards* developed the Teams-Games-Tournament (TGT) (Devries, 1980) model at Johns Hopkins University; however, these alternative methodologies have failed to address the learning barriers prevalent in students, and the impact of these strategies is still insufficient (Krichbaum, 2017). Many students have difficulty in handling the concepts, applying them in a real context and solving problems in their environment, because their knowledge usually has gaps; nevertheless, the system-by-system approach (cardiovascular, pulmonary, vascular) allows the student to understand the overall impact and changes at the systemic level (Pere Pujolàs, 2015).

Latin America is facing changes in medical education promoted by Ministries of Health and Education, as well as the situation generated by the COVID-19 pandemic, which have impacted the training of personnel in all branches of health. The changes that are required should improve the quality of healthcare professionals, with the aim of training more critical and analytical professionals whose learning is based on the ability to use resources to search for, evaluate and apply information, as required for the problems of their context (V, 2019)**Invalid source specified.**. Physiology must evolve to empower the student so that they can give answers to physiology problems and predict systemic changes, providing a cooperative learning environment based on their skills and abilities, in face-to-face, virtual or hybrid environments. The year 2020 challenged teachers in all areas, since the need for efficient and quality virtual education became a priority (Pere Pujolàs, 2015), (Galban, 1998); however, these educational experiences remain in the classroom and it is important to reflect on didactic alternatives in face-to-face, virtual or hybrid medical education.

The aim of this study was to analyze the educational experience in the physiology course of the medicine program of a higher education institution in southern Colombia from 2018 to 2019. In addition, this study established the influence of the preferred type of learning, as measured by Herrmann's Brain Dominance Instrument, on the pass rate of the human physiology course as well as searching for any relationships with age and sex. Furthermore, a qualitative approach was used to explore categories related to students' perception of meaningful learning associated with both collaborative learning (laboratory sessions, case-based learning) and cooperative learning (challenge-based learning), and to understand their learning dynamics.

2. Materials and Methods

This study was conducted with an exploratory sequential mixed-methods approach with a qualitative focus, during the semesters between 2018 and 2019 at Fundación Universitaria Navarra (UNINAVARRA) in the city of Neiva, Colombia. A total of 204 medical students participated. The inclusion criteria were as follows: being enrolled in the third semester of Medicine; taking the physiology course for the first time and accepting participation voluntarily. The students gave their consent to be included in this study and could freely express their points of view. Some semistructured surveys were anonymous so as to ensure authentic responses. Furthermore, students were free to withdraw from the study at any point. The study was approved by the UNINAVARRA ethics committee. The study was carried out in four phases, based on C. Chadwick's Teaching Instruction Model (Fig. 1) (Chadwick, 1990).

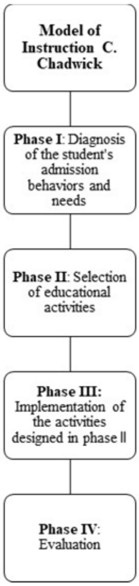

Figure 1: Chadwick's Teaching Instruction Model

Phase I: A diagnosis of the students' behaviors and needs was made by applying Hermann's Brain Dominance Instrument upon starting the course (Cazau, 2005), which gave an overview of the learning types found among the group of students by classifying them by their dominant type of thinking. The model defined their dominance as one or more of the following: Left Cerebral (LC), Right Cerebral (RC), Left Limbic (LL), Right Limbic (RL). Herrmann assigned strengths and weaknesses to each of these learning styles, as well as strategies to maximize learning (Cazau, 2005). For example, LC students tend to be cold and detached but intellectually bright, with critical, analytical and logical reasoning skills, yet are highly competitive and individualistic. For this particular group of students, learning depends on hard facts, lectures and tangible mathematical data. Another example is its opposite: students who are classified as RL are usually extraverted, emotional and spontaneous; their learning is more associated with experience and depends on empathy with others and even with the teacher; they are good at teamwork, and have skills in oral and written expression. Participants with more than one dominance share characteristics of each group, and some people demonstrate whole-brain learning (Cazau, 2005). Given that there are doubts about the relevance or veracity of the results of any learning scale/cognitive style model or if learning styles truly exist (Nancekivell, 2020), (Willingham, 2010) , students' preferences were also recorded regarding their ways of studying and learning, as well as on the subject of their teachers. All this information gave an idea of the characteristics that the study guide should have, and the techniques and methodologies that should be employed.

Phase II: A didactic guide based on cooperative learning was designed and implemented, with the aim of putting the contents of the course into practice in accordance with the learning styles identified. For each core theme, didactic methodologies were included to suit each type of student and, in addition, heterogeneous groups were formed according to the results of the diagnosis of educational needs; that is, teams were composed of students with different learning types and they had to solve the problem or challenge of each stage together. The objective of this was that each individual member would contribute their skills, but also strengthen areas that were difficult for them. Educational activities were selected for each group of students. The activities were based on the constructivist theory. The methodologies used were: problem-based learning (PBL), for example using research questions and setting out problems with gaps in physiological knowledge; case-based learning (CBL), for example solving physiological problems based on cases involving healthy people, and predicting possible physiological adaptations; gamification or game-based learning, for example a trivia quiz with questions and answers on a certain topic with prizes for some students, a game to place electrocardiogram electrodes in the correct position using balloons, a game of capture the flag using questions and answers, among others; challenge-based learning (CBL), based on three steps: participation, research and act on one of the specific topics until coming up with an output, for example, making a model of the respiratory system using recycled materials and an energy source to observe the mechanics of respiration;activities in the physiology laboratory, which were carried out using the Labstation® and Labchart® software fromAdintruments®; and practical outdoor exercises. Table 1 shows the thematic content addressed throughout the physiology course and the distribution of study hours for each core theme.

Table 1: Thematic contents

N°	THEMATIC	STUDENT DEDICATION			TOTAL HOURS
		HFF*	HL*	HI*	
1	**Cell and muscle physiology** Methodology: ABP, ABR, Outdoor Exercise, Physiology Laboratory	21	11	32	64
2	**Cardiovascular and circulatory physiology** Methodology: ABP, ABR, Blood Physiology Laboratory, Electrocardiography Laboratory, Integration Games.	22	11	32	65
3	**Respiratory physiology** Methodology: ABP, ABR, Laboratory of respiratory physiology and spirometry	22	11	32	65
4	**Renal physiology** Methodology: ABP, ABR, Laboratory of renal physiology (analysis of urine samples)	21	11	32	64
5	**Endocrine physiology and metabolism** Methodology: Master classes, ABP, ABR	21	10	32	63
6	**Gastrointestinal physiology** Methodology: Master classes, ABP, ABR	21	10	32	63
TOTAL		128	64	192	384

HFF: Hours of face-to-face study HL: Hours in the Lab HI: Hours of independent study

Phase III: The activities designed in phase II were implemented in a collaborative and reflective environment, achieving the active participation of students in groups. Students' and teachers' independent, directed and face-to-face hours of study were respected. A photographic record and a field diary were kept.

Phase IV: An evaluation of the learning objectives achieved by the students and the efficiency of the model was carried out. For this purpose, a group interview was conducted to evaluate the students' perceptions of the methodological activities. Four focus groups were conducted, one for each semester, in which the entire sample participated. Anonymous, written, semistructured surveys were given to groups of 60 students. Additionally, professors from outside the course conducted interviews with groups of 6 to 8 people in which verbal responses were recorded. All the qualitative information collected was transcribed and analyzed systematically using the software ATLAS.ti. The following discussion-generating questions were asked in the focus groups:

- What is your opinion about the methodologies and activities employed in the physiology course and the role have they played in your learning?
- Do you think that collaborative work contributed to your learning?
- What observations do you have about the class and how it could be improved?

The information was analyzed from qualitative and quantitative approaches. Firstly, a descriptive statistical analysis was performed by calculating measures of central tendency and dispersion for the quantitative variables, and frequency distribution for categorical variables. Normality tests were performed, and parametric and non-parametric measures were applied according to the distribution of the variables. The epiR package was used to carry out a chi-square test using a significance of less than 0.05. Following this, a qualitative analysis was carried out using a descriptive phenomenological approach. Once the transcription of the focus groups was completed, content analysis was carried out with a hermeneutic-interpretive method that involved coding the emerging categories, which enabled us to consolidate the students' perceptions.

3. Results

3.1 *Quantitative Analysis*

Physiology students enrolled in the 2018-1, 2018-2, 2019-1 and 2019-2 semesters were included in a cohort to be monitored once inclusion and exclusion criteria were met. A total of 204 students were included, of whom 74 were male (36.2%) and 130 females (64%), with an average age of 19.5 years. According to the assessment of learning styles, based on Herrmann's Brain Dominance Instrument, the most common style was single dominance in the left cerebral (LC) zone, as found in 52 students (25.4%). In fact, 123 students (60.3%) had a left cerebral preference, either on its own or in combination with other styles, while 61 students (29.9%) had the right cerebral (RC) style as one of their preferences, including 26 participants (13%) who had this as their only dominance. Only 3 students (1.5%) demonstrated a whole-brained style of learning and another 3 did not respond to the evaluation (Table 2).

Table 2: Participants student characteristics

Datos	**n (%) 204**
Sex	
Male	74 (36,2)
Female	130 (63,7)
Age, (Years)	
Average (s.d)	19,5 (2,7)
Average final grade	
Average (s.d)	3,1(0,39)
Brain Quadrant Model Assessment	
LC	52 (25.9)
RC	26 (12.94)
LL	30 (14,93)
RL	10(4,98)
LC+RC	17 (8,46)
LC+LL	39 (19,4)
LC+RL	9(4,48)
RC+RL	2 (1)
RC+LL	10(4,9)
LC+RC+LL	3 (1,5)
Global intermediate	3 (1,5)

Table 3 shows the percentage distribution of learning styles according to sex. 32.4 % percent of the males and 21.5% of the females were assessed to have a LC learning style, while 18 % of the males and 20% of the females were found to have a combined left cerebral and left limbic (LC+LL) preference. A statistically significant association was found between males and the LC learning style (P=0.04) and between females and right limbic style (RL) (P=0.03); however, the other associations for male or female students were not statistically significant.

Table 3: Association between sex and learning style according to the Brain Quadrant Model

Date	Female (%) 130	Male (%) 74	P	Or (ic 95%)
Age Mean (standard deviation)	19,3 (2,2)	19,9 (3,3)	N/a	N/a
Brain Quadrant Model Assessment				
LC	27 (20,7)	25 (33,7)	0,04*	2.0 (1,1- 4,0)
RC	16 (12,4)	10 (13,8)	0.49	1,4 (0,5- 3,82)
LL	18 (13,9)	12 (16,6)	0.41	1.4 (0,5- 3,86)
RL	6 (4,6)	4 (5,5)	0,73	1,2 (0,3 – 5,4)
LC+RC	11 (8,5)	6 (8,3)	0,74	1.2 (0,37-3,9)
LC+LL	26 (20,1)	13 (18,0)	0.73	1,1 (0,4-2,8)
LC+RL	6 (4,6)	3 (4,1)	0,83	1.1 (0,25-5,4)
RC+RL	1 (0,7)	1 (1,3)	0.64	1,9 (0,1- 35,0)
RC+LL	4 (3,1)	6 (8,3)	0,06	3,9 (0,9- 16,0)
LC+RC+LL	2 (1,5)	1 (1,3)	0.9	0,85 (0,06-10,6)
Global intermediate	2 (1,5)	1 (1,3)	0.9	1,0 (0,08-13,2)

Table 4 shows the relationship between passing rates and the learning style measured in the initial phase of the study. 78% of female students and 70% of male students passed and there was no statically significant relationship between passing the course and sex or age. Only the LC learning style showed a statistically significant association (p=0.04). The average final grade was 3.1 out of 5 (SD 0.39) and the overall fail rate (i.e. students who scored below 3.0) was 24%. However, the percentage of students failing the course in semesters prior to the implementation of the didactic guides based on the different learning types was 35% to 45%.

Table 4: Association between the final grade of the course according to sex, learning style and age

Date	Approved	Reproved	P	Or (ic 95%)
Sex (%)				
Female	99 (78)	28 (22)	0.24	0.67 (0.3 - 1.3)
Male	52 (70,2)	22 (29,7)		
Age Mean (standard deviation)	19,52 (2,67)	19,62 (2,66)	0.82	N/a
Brain Quadrant Model Assessment				
LC	39 (76,4)	12 (23,5)	0,76	0.90 (0.3- 1.99)
RC	19 (76)	6 (24)	0.87	0.9 (0.2- 2.6)
LL	19 (63,3)	11 (36,6)	0.11	1.9 (0.75- 4.6)
RL	8 (80)	2 (20)	0.69	0.72 (0.07 - 3.8)
LC+RC	10 (58,8)	7 (41,1)	0.11	2.2 (0,67-6.9)
LC+LL	34 (87,1)	5 (12,8)	0.04*	0,3 (0,1-0,99)
LC+RL	6 (66,6)	3 (33,33)	0,56	1.5 (0.2-7.3)
RC+RL	1 (50)	1 (50)	0.4	3 (0.03-237.0)
RC+LL	7 (70)	3(30)	0,7	1.2 (0,2-5.9)
LC+RC+LL	3 (100)	0 (0)	0.3	0 (0-3.8)
Global intermediate	2 (100)	0 (0)	0.4	0 (0-5.7)

4. Qualitative Analysis

The responses of the focus groups were guided to keep them on topic, avoiding deviations and discussions that did not contribute to the objective of the study. Once the interviews were transcribed, content analysis was conducted under the hermeneutic-interpretive method. This analysis was used to consolidate the students' perceptions under the following emerging category: Contribution of collaborative work to learning during the physiology course.

The didactic strategy based on collaborative and cooperative work made it possible to identify that the students appropriated the course subject matter in a positive way, highlighting the use of creative and challenging activities that put students' skills to the test. We highlight the following perceptions given by different participants:

P1: "What I liked the most was the emphasis on the most important topics, since the topic is not finished until it is clear [to the students]".
P2: "During this course I managed to understand a lot about physiology since the subject does not evaluate memory, but rather learning. The teacher is very prepared and satisfactorily solves all the doubts".
P3: "I liked the didactic help in some classes such as workshops, craft-based tasks and classwork exercises, which helped us to improve our knowledge".
P4: "I liked how the teacher gave us the different activities because that helps the student to learn more and investigate, also helping to improve their grades during the section of the course".

This sample of comments shows that collaborative and cooperative learning strengthen students' appropriation of the subject matter of the course. Additionally, by basing the activities on problem solving, students develop skills that allow them to address real situations with practical solutions, relating concepts and theory with medical praxis.

Another aspect that is strengthened with the use of this strategy is students' critical thinking and research skills. Collaborative and cooperative learning allows the student to learn through case studies relevant to their profession, while controlling the conditions and demanding a rounded and well thought out response to the case presented.

It is important to note that, although the strategy aims to make use of team activities, the medical students do not highlight it. There were no comments highlighting teamwork as a didactic strategy. Instead, it was found that there were problems within the groups formed:

P5: "Students should be given the opportunity to change groups when they definitely do not feel satisfied with theirs".

Medical education has evolved at a slow pace in educational theories, from the Socratic class, through the PBL strategies in medicine that emerged in the 1970s at McMaster University, to evidence-based medicine since 1992, which is the subject of controversy, and it is striking that the students' perception does not highlight the importance of collaborative work. This is consistent with studies such as *Andrés et al*., in which, in spite of the positive results evidenced in the students' academic results, there were no differences in the results of the qualitative analysis regarding students' perception of the importance of cooperative or collaborative work (Andreu Andrés, 2016).

5. Discussion

The results of this study showed a sex distribution similar to previous works: 64% of participating students were female and the average age was 19.5 years. *Dobson et al.* found 75% female and 25% male students in their analysis; they also included students who had mostly completed the anatomy course and were in their second year, like the students included in the present study (Dobson, 2009). *Wehrwein et al.* and *Hughes et al.* analyzed groups of students in which the majority were female with a mean age similar to that found in this study (19.7 years) (Erica A. Wehrwein, 2007), (Mathew Hughes, 2016). Despite the evident inversion of the gender ratio in undergraduate medicine, gender inequality is still present in particular for medical specialties and to an even greater degree in surgical specialties, where inequalities and discrimination against women are still observed, as reported by *Trinh et al.* (Lily N.Trinh, 2021), and there are also difficulties in the recognition of both research and academic achievements in professional life (Janis M. Miyasaki, 2020).

In this study, some activities were adjusted taking into account the results of the learning style analysis; however there is little empirical evidence to support this, or the studies that do so have substancial limitations, like *Hughes et al.*, in which the authors came to the conclusion that a "whole-brained" approach is possible, but it depends on strategically designing the teaching methods used in the courses and modules, not simply by random selecting activities (Mathew Hughes, 2016). It was interesting to implement the different teaching styles, and it was a helpful way to organize the activities without ignoring the opinions of the teachers and students. There are very few independent studies on the reliability and validity of the Herrmann Brain Dominance Instrument (HBDI) and "whole brain thinking". *Nancekivell et al.* surveyed the prevalence of belief in the importance of learning styles among both educators and non-educators. They identified that those who worked with young children ere more likely to interpret learning styles in an essentialist way, and their findings demonstrated that beliefs about learning styles are much more complex than previously thought (Nancekivell, 2020). Several authors have conducted a learning style assessment upon beginning courses to design didactics to fit students' needs; *Dobson et al*., (Dobson, 2009) *Wehrwein et al.*, (Erica A. Wehrwein, 2007) and *Breckler et al.* (Jennifer Breckler, 2009) conducted initial assessments of learning styles with the VARK (Visual, Auditory, Reading/Writing, and Kinesthetic) model. These findings are concordant with those of *Koju et al.*, in which the second most common learning type was an RC preference (Bibek Koju, 2019). Both of these studies had findings that were similar to those of this research. In all the publications where learning styles were analyzed, it was concluded that they are a useful tool for designing didactic strategies and mentioned that they have an impact on learning outcomes. However, we also found authors like *Riener et al*., who consider that there is no credible evidence that learning styles exist (Willingham, 2010). In this study, it was useful as a starting point, but the individual and collective perceptions of the students and teachers regarding the methodologies that could have an impact on learning were taken into greater consideration.

The most frequent learning style was LC dominance (25.9%), followed by LC+LL dominance (19.4%). In fact, 60.3% of participants had an LC dominance, on its own or in combination.

With respect to the relationship between sex and learning style, as mentioned above, 32.4% of male and 21.5% of female students were found to have an LC learning style, while 18% of males and 20% of females were assessed as having a combined LC+LL style. Several authors have related learning style to sex and have found significant differences between the sexes when measured with the VARK model. In this study, although the whole brain model was used, statistically significant differences were found only in two categories: LC and RC. However, the findings on the hormonal, genetic and epigenetic influence on brain development associating sex and learning are unreliable, given that there are multiple environmental, gestational and other complicating variables that have not been taken into account (Erica A. Wehrwein, 2007), (Arnold, 2011), (Olga Viviana Torres Teran, 2019), (Marcela Bitran C, 2004), (Bertha Marlén Velásquez Burgos, 2007).

The course pass rate was not statistically associated with gender and age. The only learning style that showed a statistically significant association with the passing of the course was LC + LL, while no other was statistically relevant. These data agree with *Keat et al.*, who analyzed learning style and found no significant association between brain preference and academic performance (Keat, Kumar, Rushdi, Nazri, & Xuan, 2016). Furthermore, *Nasr et al.* and *Koju et al.* found no significant correlation between academic performance and learning style preferences of the participants in their studies (Bibek Koju, 2019), (Nasr et al. 2016). These findings have been related to differences between students' study methods as well as the way they perceive or understand information, which is related to their previous knowledge and experiences; many students are unaware of their learning style, which may hinder their achievement of learning objectives. It also becomes important to explore examination styles, which are usually the same for all students and may not be related to their knowledge (Bibek Koju, 2019), (Olga Viviana Torres Teran, 2019).

The final average grade was 3.1 out of 5 (SD 0.39), which demonstrates the difficulty of passing this course given that 24% of students failed to achieve the passing grade of 3.0. Several authors have reported students' perspective on physiology courses, which they consider complex, and it has been shown, according to *Sturges et al*., *Michael et al.* and *Slominski et al.*, that this is due to the characteristics of the discipline and the mathematical and scientific challenges that the student must overcome to pass it (Cazau, 2005), (Michael J. A., 1998), (Diana Sturges, 2016).

In the qualitative analysis, an emerging category of analysis was identified (the contribution of collaborative work to learning during the physiology course), which made it possible to consolidate the students' perceptions. *Essop and Beselaar* found that the implementation of cooperative learning in large classes in South Africa had a relatively good reception among the students with some indication of group work, was logistically feasible in relatively large classes, although it requires adequate support, and that additional measures need to be adopted to ensure its success (Beselaar, 2020). Collaborative and cooperative learning is a strategy that permits the development of topics through the interaction of students, thereby promoting teamwork and problem solving, reducing competition, and increasing the active participation of each student in each proposed activity. In this regard, the findings of this study were similar to those of *Essop and Beselaar* although in this case there was no express recognition from the students; however, we did find an improvement in students' individual and group performance, as well as in their perception of the course, as seen in the qualitative analysis.The strategies proposed in this work were also framed in cooperative work, since the assignment of individual responsibilities to each student within the group was carefully planned. This is consistent with what is expressed by *Echeita et al.*, who discussed the advantages and disadvantages of cooperative learning (Echeita, 1995), and *Davidson et al.*, who described the similarities and differences of cooperative, collaborative and problem-based learning, as well as the ways that can be integrated into courses (Major, 2014). This strategy is widely employed at different educational levels; although its use is still limited in medicine, given that much of the knowledge depends on individual work and evaluation focused on behavioral aspects, it has nevertheless been gaining space. The implementation of this strategy in health programs dates back to recent years, obtaining mixed results: some positive and some inconclusive. One example is in the study by *Chen et al.*, who observed two groups, one of which was involved in cooperative learning and the other continued in the traditional way. The intervention group obtained better academic results that were statistically significant and expressed that they were able to "*cultivate awareness of the importance of team cooperation and improve students' ability to analyze and solve problems*" (Huff 1997). Other studies like *Zhang et* al. evaluated the impact of cooperative learning on critical thinking and concluded that clinical practice based on cooperative learning is useful for boosting students' critical thinking skills. This study did not assess critical thinking, but it did observe better performance in the activities that require abstract thinking, such as problem solving based on situations of physiological adaptations (BowenChenb, 2020).

As for the present study, the use of the didactic strategy based on collaborative and cooperative work allowed us to identify that students appropriated the subject matter of the course in a positive way, highlighting the use of creative and challenging activities that put their skills to the test. By basing the activities on problem solving, students develop skills that allow them to address real situations with practical solutions, relating concepts and theory with medical praxis; these results were comparable to those found by *Yeo et al.* at Kyungpook National University School of Medicine in Korea, where they evaluated a constructivist educational strategy (PBL) that had been implemented since 1999. *Yeo et al.* followed up for 16 years, and found that students' perception of these teaching strategies improved over time, as well as the teachers' implementation (Chang, 2016).

6. Conclusion

The aim of this study was to analyze the educational experience in the teaching of physiology, in order to highlight and reflect on the knowledge that leads to the evaluation of didactic practices in this area, based on collaborative learning. During the development of this work, we contributed to the construction of conceptual tools related to physiology education, given that in the literature review, it is evident that there is a concern among students and teachers from different schools about how to make a contribution to problematizing teaching practices in a university space; these are more related to the very nature of the discipline, a fact that is relevant given that both qualitative and quantitative findings were similar in culturally different populations. The most relevant pedagogical-didactic category identified was the contribution of collaborative work to successful learning during the physiology course, as participation in it led to significant learning by physiology students.

This study had some limitations: in the quantitative analysis, it was not possible to find any association with socioeconomic level and group dynamics partly because the written surveys were anonymous. These can be confounding factors for the relationships between grades, sex and learning style, among others. Furthermore, although the brain dominance instrument was useful when planning some activities, these evaluations are subjective and therefore students' opinions were also taken into consideration when designing the activities.

7. Author Contributions

CYRT and CRG conceived and designed the research; CYRT, LPM and CRG analyzed the data; CYRT, LPM and CRG interpreted the results of the experiments; CYRT, LPM and CRG prepared the figures; CYRT and CRG drafted the manuscript; CYRT and CRG edited and revised the manuscript; CYRT, LPM and CRG approved the final version of the manuscript.

8. Compliance with Ethical Standards

This study was approved by the Ethics Committee of the Navarra University Foundation and each participant signed informed consent information and voluntarily participated. No conflicts of interest, financial or otherwise, are declared by the authors.

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