

Article

Cooperative Learning for a More Sustainable Education: Gender Equity in the Learning of Maths

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Abstract: Education and gender equity are of high priority in the list of objectives when looking to achieve sustainable development; however, various studies have analysed that these objectives are far from being reached. The goal of this paper was to investigate the influence that cooperative learning has on academic performance and on the gender gap in the subject of Maths. A total of 14,122 students between the ages of 10 and 19 took part in the study. The hypothesis posed was that gender differences observed in Maths would significantly be reduced in those classrooms in which cooperative learning had a higher degree of implementation. In the results, the analysis of the regression of means and gradients showed that gender predicts Maths results in a positive manner (estimated beta = 0.12, $p < 0.01$) and interacts with cooperative learning by taking a negative value (−0.26) and with an associated critical value less than 0.05. In other words, the relation between cooperative learning and Math grades is significantly higher in males than in females. However, females achieve better marks, which generates a certain relation of equity. These results prove that cooperative learning can reduce gender differences in the learning of Maths.

Keywords: sustainable education; cooperative learning; gender equity in mathematics



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1. Introduction

In spite of the fact that sustainable development has become one of the greatest challenges of our society, education has not as yet, acquired the necessary prominence that is presupposed in this respect. In recent years, although there are several studies that have contributed substantial progress and knowledge in the field of education for sustainability, these seem not to suffice for the complex challenges we are facing nowadays [1,2].

Not only is education a means to meet an objective, but it is also a goal. In this respect, education plays a transformative role; relevant issues on social development should be tackled and values of cooperation, solidarity, equity and inclusion should be promoted. All of these should be done taking into account the singularity of each individual. However, until now, the internal dimensions of individuals have been neglected in the area of education on sustainability [3,4]. Only recently has it started drawing increasing attention in the fields of sustainable science as well as education [2,4,5].

Among the Sustainable Development Goals (SDGs) of the United Nations, the global education goal (SDG 4), emphasizes ensuring an inclusive and equitable quality education and promoting lifelong learning opportunities for all [6]. It brings to light the need to rely on holistic pedagogies capable of addressing the current challenges. These active teaching methods contemplate learning as a dynamic process in which students play an active role, learning from experience and interacting with their peers [7]. Cooperative learning (CL), which is one of these pedagogical models, has been described as an educational approach based on the collaborative work of small groups of students who share a common objective and who, through their interaction and dialoguing, create their own learning [8].

A myriad of research papers have reported the benefits of CL in different educational fields [9,10]. However, the specific characteristics of different subjects may favour that some adapt to this pedagogy better than others. For example, a meta-analysis based on 65 pieces of research in different educational fields found statistical differences in linguistic-related subjects and those pertaining to exact sciences such as Maths [11]. This, in turn, confirms that it is essential to investigate the relation of the subject and the methodology used.

It is obvious that all educational subjects are relevant for sustainable development. However, it is well-known that Maths is a basic cornerstone in education: those students who acquire a good knowledge of Maths are more likely to obtain better qualifications and obtain better educational careers than those who have a lower performance in Maths [12]. Consequently, educational policies seriously take into account the indicators that various reports provide on this subject. For example, one of the most important reports is the PISA (Programme for International Student Assessment), of the OECD (Organisation for Economic and Co-operation and Development) which measures 15-year-olds' knowledge and ability in reading, mathematics and science. The PISA assessment includes OECD countries and a number of non-member countries, called "partners", and it is conducted every 3 years. The PISA, recognised internationally, has become a means of learning what educational differences exist among countries, and sometimes, even within a country. Furthermore, the results of this report in subjects such as Maths are seen as an indicator of the educational policies implemented in the different participating territories, as well as a tool to explain the type of educational strategies that seem to work better [13,14].

For this reason, finding formulas that implement academic performance in Maths has become a priority goal in the different educational policies. Among the several factors that seem to intervene in mathematical performance, gender is one of the variables with higher capacity of predicting success [15]. In this sense, several research articles have analysed differences between sexes, finding that female students show negative attitudes and lower performances. For example, it has been reported that female students feel more insecure and consider Maths boring and difficult to a greater extent than male students [16,17]. On the other hand, male students feel more self-confident [18], with a higher intrinsic motivation towards Maths [19] and a lower degree of anxiety [20,21]. In terms of performance, the gender gap in favour of boys in different stages of education has been highlighted [13,22,23]. Moreover, gender differences have been made clear in international PISA assessments. According to the last report [24], boys obtained results that were five points higher than girls on average in the OECD countries, and six points higher in Spain.

According to the UN's goal 5 (SDG5) of sustainable development, the gender gap is one of the aspects that awakes more concern nowadays. SDG5 states that women's effective participation and leadership opportunities should be guaranteed, thus confirming that gender stereotypes are among the main challenges with regard to equality in the goals of sustainable development.

It is believed that these gender differences should show a disappearing tendency with the application of new methodologies that promote equal participation [25–27]. In this way, CL stands out as one of the essential teaching methods to promote inclusive education [28], and it is considered a valid technique to develop social relationships and competences to promote gender equality [29]. Furthermore, there are numerous research studies that have confirmed the positive effects of CL on attitude, motivation and academic performance [30–32].

However, if CL is not implemented adequately, it can exacerbate problems of equality in the classroom by supporting successful students while leaving aside the less successful ones [33]. For example, it has been reported that the greatest problem of CL implementation is determined by how rigorous the planning is and the lack of prior knowledge of the teaching staff [34]. Previous studies concluded that teachers who used CL in their classrooms did not have enough previous knowledge and adequate language patterns to achieve the essential elements of this methodology [35]. It is clear, therefore, that teacher training plays a key role in CL, however, it is not usually taken into account when implementing this methodology [36].

It is therefore unclear whether CL implemented by teachers with adequate training is an effective method for gender equality in Maths, where gender differences are significant. Finding pedagogical strategies that promote an inclusive and equitable quality education, as well as promote gender equality is undoubtedly one of the main challenges in sustainable development.

Aim of study and hypothesis.

The aim of this research paper is to analyse the influence that CL implementation has on academic performance and gender equality in the subject of Maths, taking into account that teachers participating in the study had received prior training in CL.

Based on the information provided earlier, these hypotheses were formulated:

1. There will be differences in the levels of implementation of cooperative learning among classes and in the academic results in Maths.
2. These variations will be related with each other so that CL will explain a better part of the inter-class groups variation with regard to academic results in Maths.
3. Gender is related to the final school year grade obtained in Maths.
4. Gender differences will significantly be reduced through the implementation of CL; in other words, an interaction between CL and gender will be found, which leads to a situation of some equity.

2. Materials and Methods

2.1. Study Background

This study is part of an ambitious project that intends to implement cooperative learning in a progressive and systematic way in all the classrooms and subjects included in the primary and secondary education in a total of 72 Spanish school centres in 25 provinces (National Network of School on Cooperative Learning).

2.2. Participants

A total of 14,112 participants from a total of 629 class groups agreed to participate. Table 1 includes the educational and sociodemographic variables with regards to the academic results obtained in mathematics at the end of the academic year. Convenience sampling was used. Previous to any data collection, each centre coordinator was informed of the protocol that had to be observed to complete the questionnaires. In May, a month before the end of the academic year, the researchers provided the students with access to the online data collecting questionnaire and let them know that any of the data collected would be kept confidential.

Table 1. Sociodemographic and educational variables in relation to Maths qualifications at the end of the academic year.

	<i>N</i>	Math Scores	95% CI
Overall	14,112		
Gender			
Males	7391	6.27	6.22, 6.33
Females	6721	6.47	6.41, 6.52
Age			
10–11	3732	7.14	7.07, 7.21
12–13	5105	6.37	6.31, 6.43
14–15	4105	5.89	6.83, 5.95
16–17 or older	1174	5.51	5.38, 5.64
Course			
Grade 5	2496	7.07	6.98, 7.15
Grade 6	2438	7.13	7.05, 7.22
Grade 7	2926	6.07	5.98, 6.15
Grade 8	2471	5.95	5.86, 6.03
Grade 9	2023	5.95	5.86, 6.03
Grade 10	1788	5.89	5.80, 5.98

The data collecting system was configured so that all the questions had to be answered before moving to the next set of questions. This ensured that all the data was collected. Consent was provided by the students' families and by the University Ethic Council.

2.3. Procedure

The organisational time frame of the project included prior training for teachers and a constant monitoring process during the entire school year. Before the school year commenced, all the teachers involved received specific training in CL methodology. The teacher training sessions lasted 20 h and special attention was given to incorporate the 5 basic elements of CL: positive interdependence, face-to-face interaction, individual accountability, group processing and social skills [37]. Considering the large number of participating schools and due to effectiveness issues, the training sessions took place in five different locations, where schools were grouped according to their geographical proximity. The training process followed the same guidelines in every location and CL methodology as an experimental technique was implemented.

After this, all Maths teachers used CL methodology to teach the subject in their classes during the school year. To guarantee the same line of action and assure the correct application of this methodology in every school, a controller hierarchical model, formed by a national committee responsible for the project, a coordinator in each of the training sectors, a coordinator in each province and a coordinator in each of the schools, was put in place. In addition, on the one hand, monthly meetings among coordinators and teachers were held, and on the other hand, the committee itself had quarterly meetings. These meetings pursued the goal of assuring an accurate monitoring process.

2.4. Instruments

The Cooperative Learning Questionnaire (CLQ) was used to check the degree of implementation of CL in each class. The CLQ [38] is formed by five secondary-scales that comprise four items each: Promoting interaction (e.g., "The members in the team interact during the completion of tasks"), Positive interdependence (e.g., "The help from my team mates is important to complete the tasks"), Individual responsibility (e.g., "Each member of the team must make an effort to contribute to the team activities"), Group processing (e.g., "The help from my team mates is important to complete the tasks") and Social Skills (e.g., "We enhance dialogue and listening and/or debating skills"). These dimensions may be grouped as a second level factor to measure cooperative learning as a whole. A common root was added to all the items in the questionnaire: "In mathematics class...". Cronbach's alphas for the original study and for the present study were respectively as follows: Social Skills = 0.74 and 0.73; Group Processing 0.75 and 0.74; Positive Interdependence = 0.72 and 0.71; Promoting Interaction 0.76 and 0.71; and Individual Responsibility = 0.79 and 0.78. The CL index was 0.89. Analysis of multicollinearity was carried out in the present study that showed a condition index above 30. This proves a moderate to strong collinearity (Belsley, 1991), which makes the exclusive use of the second level factor more advisable. Furthermore, this indicator was more adequate for the purpose of this study.

2.5. Sociodemographic Variables

Apart from the variables gender (0 = male, 1 = female) and age (0 = 10–11, 1 = 12–13, 2 = 14–15, 3 = 16–17 or older), the other condition included was the grade (0 = Primary School, 1 = Secondary School). The final Maths score was also included (0–10).

2.6. Study Design and Data Analysis

This research is an ex post facto study with a prospective character. The present study used a single group or "simple design". Later, this transversal data was analysed descriptively and correlationally.

In order to test the enunciated hypothesis, the MIXED procedure of the SPSS was used, so that a particular kind of model known as hierarchical linear [39], multilevel [40]

or random coefficient model [41] could be adjusted. These models have been proposed to analyse data where the data are grouped by wider information units and measures are taken, both at the lowest (students) and at highest levels (classes).

The first regression model did not include independent or predictive variables. It is known as a fully unconditional model, and it determined the variation in Maths scores at the class level, plus those variations attributable to individual factors. This model offered several global adjustment statistics that indicated to what extent the proposed model was able to represent the variability observed at data level (the lower the statistic values, the more tightly the model adjusts to data). The first of such statistic values is variance $-2LL$ [42]. The rest of them are variations of $-2LL$, which affect (increase) its value by, basically, some function of the number of parameters. The second statistic value is Akaike Information Criterion (AIC) [43]; the third value is (BIC) Bayesian Information Criterion [44]. The study also included covariance estimates: estimations on the parameters affected by the random effects of the model. The factor variance (class) indicated the degree of variation of the dependent variable between classes in the whole population, and the variance of residuals indicated how much the dependent variable varied within each class. Based on this information, the intraclass correlation coefficient (ICC) was calculated. The second model analysed the independent contribution to the prediction of the mathematics scores for the following predictors: Level 1, Gender (male 0, 1 female), age (ordinal 0 = 10–11, 1 = 12–13, 2 = 14–15, 3 = 16–17 or older); Level 2, Cooperative Learning Index (scale 1–5, based on the group average), Grade (0 = Primary School, 1 = Secondary School). The third model was a random coefficient model because it let both coefficients (intersection and slope) vary randomly from class to class (different combinations were included, but only significant effects were mentioned). Finally, the fourth model included the interaction between cooperative learning and gender and allowed us to face one of the hypotheses of this study: Does cooperative learning enhance gender equality in mathematics learning?

3. Results

3.1. Preliminary Analysis

The completed descriptive analysis showed that CL was being regularly implemented in the classes ($M = 3.84$, $DT = 0.65$). Nevertheless, the random effect single way unbalanced variance analysis (ANOVA) showed that CL varied significantly between classes ($\chi^2(607) = 1542.28$, $p < 0.001$).

3.2. Multilevel Analysis

In the first regression model, which was fully unconditional, the factor variance (class = 0.75) indicated the degree of variation of the dependent variable between classes in the whole population, and the variance of the residuals (residual = 3.99) indicated how much the dependent variable varied within each class. According to these estimations, the variability of the centres represented $(0.75)/(0.75 + 3.99) = 0.158$. Approximately 16% of this was due to interclass variability, while the remaining 84% represented intraclass variability. Since both types of variability may be reduced by means of independent variables of the right level, Model 2 was constructed. The estimate value of the residuals (3.72) was less than the estimate value of the null model (3.99). When these two estimates were compared, we found the ratio of the variance explained at level 1: $(3.99 - 3.72)/3.99 = 0.068$. The intracentre variability was reduced by approximately 7%. The proportion of variance explained at level 2: $(0.75 - 0.37)/0.75 = 0.507$, was at approximately 51% (Table 2).

Table 2. Unconditional or empty regression model (1) and constants or random intersections model (2).

Parameter	Maths				
	Empty Model 1		Model 2		
	B	SE	B	SE	t
Fixed effects					
Constant	6.33 ***	0.04	5.73 ***	0.26	21.92 ***
Level 1 Variables					
Gender			0.11 ***	0.03	3.42 ***
Age			0.09 *	0.04	3.39 *
Level 2 variables					
Cooperative learning			0.29 *	0.11	2.51 *
Educational Stage			−0.87 ***	0.09	−9.51 ***
Random effects					
Variance between students (Residual)	3.99 ***	0.05	3.72 ***	0.05	
Variance between classrooms (students = class)	0.75 ***	0.05	0.37 ***	0.03	
Deviance (−2 log likelihood)	60,619.98		59,328.61		
Akaike information criterion	60,625.98		59,350.61		
Bayesian information criterion	60,648.65		59,433.71		

Note: * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

3.3. Regression Model (1) and Random Intersections Model (2)

Model 3 intended to adjust all the variables from possible random effects, but only the gender variable turned out to be of any significance. Table 3 includes the estimates for the four covariance factors included in this model: residual or error variance, average or intersection variance, NE (1.1) slopes' variance, NE (2.2) and covariance between variables and slopes, NE (2.1). The residual variance shows how much students divert from the regression line in their classes. When the gender is included in the regression model by applying a customized equation for each class, the intraclass variability was reduced by approximately 8%. The variance of the slopes was significant ($p < 0.001$). Therefore, we may conclude that the regression equation for each class was different (the relation between gender and mathematics score varied across the classes' population).

Table 3. Random coefficients regression model (3) and means and slopes as results regression model (4).

Parameter	Model 3			Model 4		
	B	SE	t	B	SE	t
Fixed effects						
Constant	5.74 ***	0.26	21.90	5.74 ***	0.26	21.91 ***
Level 1 Variables						
Gender	0.11	0.03	2.96 **	0.12 **	0.04	3.04 **
Age	0.09 *	0.04	2.34 *	0.09 *	0.04	3.39 *
Level 2 Variables						
Cooperative Learning	0.28 *	0.11	2.43 *	0.65 **	0.20	3.18 **
Cooperative learning* Gender	-	-	-	−0.26 *	0.12	−2.20 *
Educational Stage	−0.90 ***	0.09	−10.23 ***	−0.90 ***	0.09	−10.23 ***
Random effects						
Variance between students (Residual)	3.67 ***	0.05		3.66 ***	0.05	
Intersection + sex (student = class)						
NE (1,1)	0.74 ***	0.14		0.73 ***	0.03	
NE (2,1)	−0.28 ***	0.08		−0.27 ***	0.08	
NE (2,2)	0.22 ***	0.05		0.21 ***	0.05	
Deviance (−2 log likelihood)	59,300.71			59,295.90		
Akaike information criterion	59,324.71			59,321.90		
Bayesian information criterion	59,425.37			59,420.11		

Note: * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

Finally, the slopes seem to be related to the averages ($p < 0.001$): the intraclass relation between gender and mathematics score seemed to increase or diminish as the size of averages did the same.

3.4. Random Regression Coefficient Model (3) and Means and Slopes as Results Regression Model

Model 4 included the interaction between cooperative learning and gender. The coefficient showed a negative value in relation with this interaction (-0.26) and was associated to a critical level of less than 0.05. Therefore, gender was negatively associated to slopes: male students' average slope was 0.26 points higher than female students'. Thus, the relation between cooperative learning and mathematics' score was significantly greater for males than it was for female students (Figure 1). In order to estimate the specific nature of these interactions, a plain slope analysis was carried out. This proved the relevance of male and female student's slopes with regards to CL values, which showed a standard deviation above and under the sample average (Bauer & Curran, 2005; Tate, 2004). Such analysis showed that female students' slope under CL predicted Maths scores (estimated beta = 0.14, $p < 0.001$) and that this relation increased for the male students' slope (estimated beta = 0.19, $p < 0.001$).

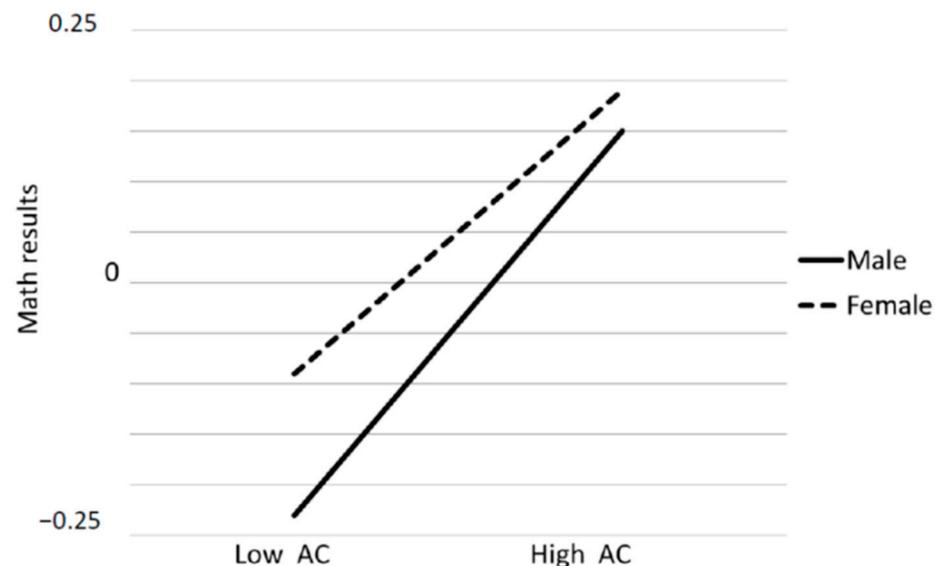


Figure 1. In order to estimate the specific nature of this interaction, a simple slope analysis was performed that verified the significance of the slopes as a function of gender in the cooperative learning values above and below the sample mean.

In order to estimate the specific nature of these interactions, a plain slope analysis was carried out. This proved the relevance of gender slopes above and under the sample average with regards to CL. With regards to the predictive value of the variables used at Level 1, we have seen that gender had a positive prediction. That is, female students had higher values compared to that of male students. Age also seemed to positively affect Maths scores. As it increased, while the rest of the variables remained constant, mathematics scores also increased.

At Level 2, CL was positively related to objective performance in mathematics. This variable by itself explained approximately 21% of the variability interclasses. School grade also had a negative effect. Thus, primary school students obtained better scores than secondary education students.

4. Discussion and Conclusions

The aim of this research paper was to analyse the influence CL implementation has on academic performance and gender equity in the subject of Maths, taking into account that the participating teachers had received training prior to the implementation.

Based on this matter, the hypothesis that there would be differences in the levels of implementation of CL and in the academic results interclasses was firstly formulated. The results of the fully unconditional model (Model 1) in Maths scores and its equivalent, the One-way Analysis of Variance Test (ANOVA) with unbalanced data of random effects for CL [45] allow for this hypothesis to be accepted. In other words, CL varies depending on the class, despite the interest in treating all students in the same way, this does not occur *de facto*. This fact could also be related to the variation in the performance in Maths (hypothesis 2). In Model 2, it can be observed that CL in the classes (variable of Level 2) significantly predicts the final grades in Maths and explains approximately 21% of the variability between classes. These results are consistent with previous studies, which have analysed the role of the group in the process of learning Maths [46,47].

However, despite the fact that all the participant teachers in this study had received the same type of prior training, it was not applied in the same manner in all the cases, which confirms that when CL is not correctly applied it can stop being effective [48]. On the other hand, an appropriate use of this methodology significantly boosts the results in Maths.

On the other hand, gender differences in Maths results have been observed in this study—women obtain higher grades than men and the variables of age and stage of education remaining constant. These results allow for the acceptance of the third hypothesis that gender is related to the final school year grade obtained in Maths. However, the findings of this study are contrary to the ones obtained by most of the studies and reports on gender and on the performance of Maths, in which an important gender gap in favour of boys is concluded [49].

Although some studies show that gender difference is decreasing or is insignificant [50,51], it must be noted that the most recent international reports indicate the opposite, showing a gender gap of eight points in favour of boys [24]. However, it is not a coincidence that the results of these same reports highlight Finland, a country whose educational model emphasises work in cooperative environments, as one of the few countries in which girls obtain better grades in Maths than boys [52,53]. The debate on the gender gap is still active and the reasons are truly complex; however, there is a certain consensus in the scientific literature that points in two directions: on the one hand, the persistence of the gender gap has been attributed to issues such as social stereotypes, and, on the other hand, the reduction of this gap seems to be related to the evolution of a traditional teaching towards the use of active pedagogies.

Some of the origins of the gender gap have been documented to be related to gender stereotypes in society that continue to be accumulated from an early age. For example, research suggests that even six-year-old boys and girls have gender views of intelligence in favour of boys [54]. These stereotypes can affect female students' self-efficacy [55] and their beliefs about their ability to perform well in disciplines such as mathematics. It is likely then, that students have a lower sense of social belonging and low self-efficacy in a math class due to these social stereotypes, which could be dampened by active pedagogies.

In the same way, it has been stated that the strategies and methodologies used with the goal to promote equity between sexes seem to have a great relevance in the learning of Maths [56]. In this study all the students worked on CL methodology. This could thus be directly related to our fourth hypothesis.

The fourth hypothesis establishes that gender differences would be significantly reduced based on CL, in other words, there could be a relation between CL and the gender of the students. The results also allow to accept this hypothesis. These findings are potentially of great importance. They indicate that CL provides the adequate educational conditions to prevent a gap in the performance between men and women in Maths. These

results could be comparable to the ones obtained using CL with participants of different cognitive levels, where the results seem to show a decrease in the gap of interclass group results [57].

Thus, CL could help to enhance equity in the learning of Maths. These results prove the studies that use CL to promote equitable learning environments for all students [58]. CL provides students with more opportunities to speak about Maths, share information, relate with other students, help their peers, learn from others, etc. [59,60]. However, if CL has not been applied in an adequate manner, it can produce the opposite effect and intensify problems of inequity in the classroom by supporting successful students while leaving aside the less successful ones [33,48]. In this study, all the teachers received prior training on CL methodology, which in turn probably had a positive influence on its correct implementation. However, continuous training and a higher degree of implementation that helps to reduce the interclass variability found in this study are necessary. In this respect, it has been suggested that the frequent use of CL does not imply a constant quality in its implementation [61,62] and it has been demonstrated that some groups or techniques can become ineffective at any moment in the CL process, so continuous training and constant monitoring are essential in order to ensure that appropriate corrective actions are taken in a timely manner [63].

Finally, the results of this research show a decrease in the performance of Maths between Primary and Secondary Education, confirming previous studies in which it has been observed that as the student advances (from Primary to the end of Baccalaureate), his/her attitude towards Maths becomes more negative [64].

This study presents various strengths, these including the large size of the sample and the variety of academic stages analysed. In addition, the logistical and pedagogical effort in the prior training of the teachers and in the subsequent implementation in schools should be noted. The findings open doors to new lines of research that is of interest and in favour of a sustainable, inclusive and equitable education.

The present study also holds some limitations. The most important one is its cross-sectional design, which does not allow to establish/confirm the changes in time as a consequence of an intervention using CL with students. Further studies should be conducted to analyse the gender gap and the results in Maths by examining, in depth and in sections, the dimensions of CL that in fact explain these changes. At the same time, it would be interesting to check if the behavioral variables of gender are related to the cooperative methodology. Likewise, future studies should analyze the influence of cooperative learning in terms of inclusion and equality on other groups such as Black students and students of other minority ethnic groups.

In conclusion, we can affirm that CL is a holistic methodology that boosts performance in Maths in an equal environment, significantly reducing the gender gap. In addition, teacher training in these methodologies seems to play a decisive role in its correct implementation, thus this needs to be given more importance in educational policymaking for a more sustainable education.

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