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Implementation of Cooperative Learning and Its Relationship with Prior Training of Teachers, Performance and Equity in Mathematics: A Longitudinal Study

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Abstract: Active pedagogies and specifically cooperative learning have been described as effective tools for inclusion and educational equity, a key concept in objective 4 within the Sustainable Development Goals. The aim of this study was to test the temporal stability of a cooperative learning (CL) over two academic years and to analyse its effects on achievement in mathematics. The sample consisted of 6456 students enrolled in school in Spain, aged between 10 and 15 years. The results showed some consistency in the use of this methodology during two school years. Mathematics scores correlated positively with all elements of CL in each of the separate school years. However, logistic regression data showed a significant drop in mathematics. In contrast, during the same period, four of the five elements of CL correlated positively with the results.

Keywords: cooperative learning; equity; mathematics; sustainable education

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1. Introduction

The aim of the global educational objective (SDG4) framed within the Sustainable Development Goals is to guarantee inclusive, equitable and quality education and promote lifelong learning opportunities for all. This objective has become the reference framework for current educational laws. In addition, it has been suggested that the SDG4 goal has strong relationships with other sustainable development goals (SDGs). Grouping SDG targets and indicators based on analyses of their best interactions can help to avoid conflicts during the implementation process and make it easier for students to engage in sustainable development [1]. Young people's knowledge of sustainability is high, but their behaviour is more affected by welfare concerns than by commitment to sustainable development. Generally, for students, sustainability implies only the care and protection of the environment; therefore, it is important to educate more on sustainability. It is clear that environmental education should not be reduced to the mere transmission of theoretical knowledge about climate change or the ecological crisis but should include both active learning and deep, constructive reflection. Additionally, COVID-19 has changed institutional priorities in relation to the incorporation of sustainability into the curriculum [2]; therefore, extraordinary effort is needed for its recovery. In this regard, the perspective of teachers plays an important role, as their degree of involvement and participation in sustainable practices is important [3]. It has been reported that teachers present systems thinking perspectives in relation to sustainable education and associate citizen action with sustainable development [4].

Consequently, it is recommended that academic goals be directed towards a competence of action for sustainability [5,6], which translates into a change in the educational model that ensures an equitable and inclusive quality education; therefore, a decisive commitment to holistic pedagogies is necessary.

In recent years, there has been particular emphasis on the need for a pedagogical renewal [7–9], which has come to fruition through the incorporation of active methodologies that conceive learning as a dynamic process in which students are the protagonists and learn from experience and interaction with their peers [10]. Cooperative learning (CL) falls within the sphere of active methodologies and has been defined as a didactic and pedagogical methodology based on work in small groups where, via interaction and dialogue, individuals construct their own learning through a common objective [11].

The effectiveness of cooperative learning depends on the harmonization of various factors. For this methodology to be efficient, it must incorporate the five essential elements of cooperative learning: (1) positive interdependence, (2) promotive interaction, (3) individual responsibility, (4) group processing and (5) social skills [12,13]. In addition, prior training must be available for teachers to ensure its correct implementation [14], and professionals must be provided with tools that facilitate control of the process by means of continuous assessment [15–17].

However, there are several proposals in which these factors are not taken into account when implementing CL in schools. Consequently, in many cases, students rarely work in a cooperative manner despite being seated in small groups [18].

1.1. Prior Training for Teachers

Research shows that the most considerable implementation problem is determined by the demanding nature of the planning process and teachers' lack of prior knowledge [19]. Previous research concluded that teachers implementing CL in their classrooms did not have sufficient prior knowledge or adequate language patterns to accomplish the essential elements of the methodology [20]. On the contrary, more recent studies reported that teachers who had received structured prior training showed a positive attitude towards the implementation of this methodology in various subjects and educational stages [14]. The aforementioned studies concur that teachers' limited knowledge of CL is a major barrier to successful implementation, hindering, for example, the correct incorporation of the five essential elements into their lesson plans.

Therefore, teacher training plays a key role in CL; however, this is not usually taken into account when implementing this methodology [21]. Thus, few studies have considered prior learning and incorporated the five core elements within their research design [14,19], although it has been suggested that when successfully combined, students experience greater benefits [22]. However, none of these investigations tested the degree of implementation after initial training. It was recently suggested that teacher training in these methodologies seems to play a decisive role in correct implementation; thus, such training needs to be emphasised in educational policy making with the goal of sustainable education [23].

Consequently, it is unknown whether prior teacher training in which the factors mentioned above are considered would facilitate the implementation of the methodology in various educational stages, particularly in area of exact sciences, for which it has been suggested that the difficulty of the task could play a differentiating role, as is the case of mathematics [24].

1.2. Literature Review

1.2.1. Sustainability and Maths

The literature includes studies describing the interaction between mathematics and sustainability with respect to three key aspects (social, environmental and economic) [24–28]. For example, in the social domain, Gutstein (2007) [24] demonstrated that teaching mathematics for social justice provides students with actions for social change and peacebuilding in the future. In the same vein, Gutstein and Peterson (2005) stated that, in solving mathematical problems, social justice issues could be used as catalysts [25]. In another study, Yaro, Amoah and Wagner [29] created real mathematics tasks to explore how science and mathematics education can inform peace, sustainability and local issues. They highlighted the challenge of adjusting the teaching conception of mathematics from an abstract topic to one that requires reflection and debate, entailing a shift in traditional pedagogy.

The environmental aspects of sustainability in mathematics education have also been described. Hamilton and Pfaff [26] addressed real-life examples related to sustainability using statistics. They asked their students to use curves and spreadsheets to assess, for example, annual changes in glaciers in Antarctica and how these changed over the years. Similarly, Steffensen et al. (2016) [28] investigated how mathematics teachers connect climate change with mathematical modelling. The authors found that teachers had strategies for using the topic of climate change in mathematics courses and mostly used climate models to teach about mathematical modelling [28]

Hauge and Barwell (2017) [30] incorporated the economic factor into social and environmental aspects through critical mathematics education. For example, the authors noted that in the context of climate change issues, students can use statistical concepts in relation to emission levels, measuring temperatures in one place and their corresponding connotations in the global economy [30].

However, ESD research through mathematics is still limited compared to other subjects. In this sense, not all subjects show the same sensitivity to sustainability. Cardeñosos, Azacate and Oliva used a sample of students from the Master of Secondary Education in mathematics, physics, biology and geology. They concluded that mathematics students were less aware of the importance of sustainability than students in the other specializations.

Recently it has been suggested that sustainability and mathematics education remain largely disconnected from the reality of the classroom [31]. A change in pedagogical model is needed to address sustainability in the area of mathematics; in this sense, active pedagogies represent promising means to achieve this goal. Lafuente Lechuga (2020) reported that active methodology helps to motivate students, even those who do not like the subject [32].

1.2.2. CL and Maths

It has been reported that in peer learning situations, less outstanding students achieve improved learning outcomes when they interact with students commencing from higher knowledge situations [33]. This scenario arises especially in disciplines linked to the exact sciences [16].

Accordingly, a significant amount of research has been conducted that has accredited the positive influence of cooperative work on attitude, motivation and academic performance in mathematics [34–38].

On the other hand, the broad consensus in the scientific literature on the benefits of CL on mathematics has led to the recommendation that this methodology be implemented in various educational stages [8]. With this objective in mind, new methods and techniques have emerged specifically for the area of mathematics and have achieved promising results [39,40]. Most studies have been focused on confirming the benefits of cooperative work compared to competitive or individual work and on finding solutions that limit the difficulties involved in implementing this methodology. However, we have not found any studies that analyse the robustness of the methodology over time. Most analyses are limited to short periods of weeks [37,41] or, at best, to one school year [14].

Therefore, it is possible that CL may lose effectiveness over time. In this regard, it has been suggested that frequent use of cooperative learning does not imply consistent quality of its implementation [42,43]. In addition, it has been shown that groups or techniques can become ineffective at any point in the CL process; therefore, continuous monitoring is necessary to ensure that appropriate corrective actions are taken in a timely manner [44]. Moreover, validated measurement instruments must be used, incorporating the five essential elements of CL and allowing for monitoring and control of the cooperative methodology over time [14].

Improving the quality of mathematics teaching and learning through CL involves the simultaneous consideration of several fundamental factors that guarantee correct implementation: the five essential elements of CL, prior teacher training and the use of measurement scales that assess the degree of implementation and its effectiveness over long periods of time.

The aim of this research was to test the temporal stability of a CL implementation programme over two academic years and to analyse its effects on achievement in mathematics. This study was conducted following a previous teacher training program in which the five essential elements of CL were contemplated. An additional objective was to gain insight into the relationship of CL with gender.

Accordingly, the following hypotheses were formulated. The first hypothesis (H1) was that well-organised and structured initial teacher training would result in a high degree of implementation of CL in schools; the second hypothesis (H2) predicted that there would be a positive correlation between CL and mathematics grades, which would be reflected in each of the five dimensions during two academic years. Finally, the third hypothesis (H3) was that gender would interact with CL, influencing performance in mathematics.

2. Method

2.1. Participants

Students enrolled in 69 Spanish schools throughout Spain participated in the study. Data collection took place over two consecutive years. The final sample consisted of 6456 students (3353 boys and 3103 girls) aged between 10 and 15 years in primary education (1st year = 2202; 2nd year = 1203; 23 lost in the system) and secondary education (1st year = 4231; 2nd year = 5063; 166 moved on to baccalaureate; 24 lost in the system). A total of 999 participants made the transition from primary to secondary education, and 166 transitioned from secondary education to baccalaureate. A convenience sampling technique was used. Prior to data collection, information on the protocol to be followed when filling in the questionnaires was provided to the coordinator of each school. In May, before the end of the academic year, for two consecutive years, students accessed the questionnaire via an online link provided by the researchers and were informed that the process and the obtained data would be confidential. Consent was obtained from parents and the Ethics Committee of the university.

2.2. Procedure

In order to participate in the study, all teachers had to receive the same training plan. The teacher training sessions lasted 30 h and were developed around the basic pillars of CL, including activities to ensure social skills, positive interdependence, individual responsibility, promotive interaction and group processing. In addition, it was specified that CL should be organised around the structure of small heterogeneous groups, and specific content on cooperative techniques in mathematics teaching was added. The teaching process followed the same pattern in all provinces, and the CL methodology was used as an experimental technique among teachers.

A hierarchical control model was established to ensure that all schools followed the same line of action. This organisational structure was made up of (1) a national commission responsible for the project, (2) a coordinator in each of the training sectors, (3) a coordinator in each province and (4) a coordinator in each of the schools. In addition, with the aim of ensuring appropriate monitoring of the process, systematic meetings were organised between the commissions, as well as between the coordinators and the teachers involved.

Once the training was completed, all centres applied the cooperative methodology in mathematics classes for two consecutive school years.

2.3. Measures

Cooperative Learning Questionnaire (CLQ)

The Cooperative Learning Questionnaire (CLQ) [15] was used to check the degree of implementation of CL in each class. The Questionnaire comprises 20 items grouped into five secondary scales: promoting interaction (4 items), positive interdependence (4 items), individual responsibility (4 items), group processing (4 items) and social skills (4 items). In addition, based on the results obtained in each of the five dimensions, the CLQ proposes a single global cooperation factor. Both first-order factorial analysis in the original sample and second-order analysis in the so-called cooperation factor presented appropriate fit indices.

2.4. Other Measures

In addition to the gender variable (0 = male, 1 = female), the final grade achieved in mathematics for each year (0–10) was collected.

2.5. Design of the Study and Data Analysis

Descriptive and correlational analyses were conducted independently for each passage. The generalised estimating equations procedure was then used to fit a repeated-measures logistic regression to study the effects of cooperative work on academic performance in mathematics among primary and secondary school students. The generalised estimating equations procedure extends the generalised lineal model to allow for the analysis of repeated measures and other correlated observations, such as clustered data.

3. Results

3.1. Preliminary Analyses

Descriptive analyses show that cooperative learning was applied regularly in lessons, with a reduction between the first and second year (Table 1). Mathematics grades were moderately high, with a reduction in the second year. All variables correlated significantly with each other at both measurement points.

Table 1. Descriptive analyses and bivariable correlations.

	1st Completion		**2nd Completion**		**Correlations**					
	M	**SD**	**M**	**SD**	**1**	**2**	**3**	**4**	**5**	**6**
1 Maths	6.48	2.12	6.39	1.96	-	0.11 **	0.11 **	0.05 **	0.08 **	0.11 **
2 Social skills	3.71	0.75	3.61	0.77	0.11 **	-	0.77 **	0.58 **	0.64 **	0.55 **
3 Group processing	3.75	0.78	3.64	0.80	0.09 **	0.75 **	-	0.60 **	0.69 **	0.53 **
4 Positive interdependence	3.81	0.77	3.71	0.78	0.06 **	0.54 **	0.56 **	-	0.68 **	0.59 **
5 Promotive interaction	3.80	0.75	3.75	0.78	0.06 **	0.60 **	0.64 **	0.64 **	-	0.56 **
6 Individual responsibility	4.26	0.76	4.18	0.80	0.10 **	0.55 **	0.53 **	0.57 **	0.53 **	-

Note: correlations of the first year are below the diagonal in the table, with correlations that correspond to the second year above the diagonal. (** $p < 0.01$)

3.2. Generalised Estimating Equation Analysis

Repeated-measures logistic regression shows a statistically significant reduction in mathematics scores (Table 2). However, 4 of the 5 elements of cooperative learning had a positive impact on the learning of mathematics: social skills, group processing, positive interdependence and individual responsibility. Gender effects were also observed, with females scoring higher than males.

Table 2. Analysis of generalised estimating equations with mathematics score as the dependent variable.

	OR	**95% CI**	***p***
Year			
1st	0.889	0.800–0.988	0.030
2nd	1.00		
Gender			
Male	0.825	0.757–0.900	0.000
Female	1.00		
Age	0.849	0.755–0.955	0.006
CL dimensions			
Social skills	1.17	1.08–1.27	0.000
Group processing	1.10	1.02–1.19	0.014

Table 2. *Cont.*

	OR	95% CI	p
Positive interdependence	0.829	0.772–0.889	0.000
Promotive interaction	1.01	0.939–1.09	0.763
Individual responsibility	1.12	1.05–1.23	0.002

Note: OR = odds ratio; CI = confidence interval, p = significance.

4. Discussion

The aim of this research was to test the temporal stability of a CL implementation programme over two school years and analyse its effects on performance in mathematics. This study was conducted following a prior teacher training programme in which the five essential elements of CL were included. The influence of gender was also studied.

The results show consistency in the use of the methodology during two school years, with a slight decrease between the first and the second year of application. Mathematics correlated positively with all elements of CL in each of the investigated school years. However, contrary to predictions, the logistic regression data showed a significant reduction in mathematics results during the period covering the two academic years of this research. In contrast, over the same period, four of the five elements of CL correlated positively with the results. These results are of particular relevance and introduce new ways of approaching the implementation of active methodologies in schools.

The research analysis corroborated the first study hypothesis, which predicted that the prior and structured teacher training would result in a high degree of implementation. The obtained results show a high rating in all the elements in both school years, confirming that prior training based on the organisation and structuring of CL is effective for implementation in a school. Recent research has shown that when CL is not highly structured, it does not produce the same positive results [45]. In the present study, all teachers received prior training in which work on the correct structure of CL was prioritised. Moreover, recent reviews warn about the lack of rigour in some implementations, for example, not including the basic elements of CL or a validation of the implementation of the model or the brevity and fragmentation of the experiences carried out [46,47]. In the current study, the five basic elements and a two-year intervention programme were included, demonstrating that the model was used adequately, and the results can be considered to be derived from it. This is important because the research needs to "prove" that the obtained results are a direct consequence of the methodology being used over a sufficiently long time frame.

Despite the high degree of implementation in both school years, there was a slight decrease in the second year with respect to all the elements. It is possible that variables not considered in this study, such as changes of teachers between school years or stages, may have influenced this aspect.

With respect to the second hypothesis (H2), it was predicted that there would be a positive correlation between CL and mathematics grades, which would be reflected in each of the elements during the two school years. The obtained data partly confirm this hypothesis. The results of descriptive and correlational analyses are in line with those reported in previous research. Zakaira et al. used a control group and an experimental group to assess the influence of CL on performance in mathematics [38] and found that the experimental group exhibited improved performance and attitude towards mathematics. In the same vein, Tarim and Akdeniz concluded that groups that had used cooperative learning techniques achieved better performance than the control groups that had used traditional methodologies [48]. In the present research, each of the elements contemplated in CL had a positive influence on mathematics performance within the same school year. However, unlike previous research, in this study, we did not use a control group; however, the large study sample and the temporal nature of the study provide reliability and consistency with respect to the results.

The most surprising finding is that with respect to the results obtained in the logistic regression of the longitudinal analysis covering the two school years, with a slight statistically significant decrease in mathematics scores. These data contradict the scientific evidence of the benefits of CL with respect to mathematics performance [23,24]. However, a deeper analysis is necessary for their correct interpretation. First, although in statistical terms, a significant reduction in scores occurred, quantitatively, it represents a decrease of only one-tenth of a point (6.4 the first year to 6.3 in the second year), which could be interpreted as a stagnation rather than a real decrease in scores. Nevertheless, bearing in mind that this negative situation is only produced when we analyse both school years as a whole and that, on the contrary, all the variables are positively related when we analyse each school year separately, it is possible that the problem is determined variables that change from one year to the next. For example, students sometimes change teachers between years, especially between educational stages. In this regard, it has been documented that the role of the teacher plays a fundamental role in the process of CL implementation [14,19,49].

On the other hand, the same students were include in the sample for both years, the cooperative groups changed based on the teacher's organization. This could be a source of conflict at the beginning of each school year. Recently, it has been documented that teachers need to know their students well enough to organise groups correctly and to foster students' interactions when working together [42]. Likewise, it has been reported that cooperative group organisation in mathematics classrooms leads to improved results in terms of academic performance [50]. Therefore, it is possible that a change of teacher could bring about a break in the consolidation of cooperative learning, significantly affecting interactions among the members of the new group. This hypothesis could justify that in this study, all elements of CL had a positive impact on the learning of mathematics (social skills, group processing, positive interdependence and individual accountability), with the exception of promotive interaction.

Promotive interaction occurs as a result of the way the teacher structures the interdependence in the group, as students can hinder, ignore or facilitate the learning of their peers [12]. For promotive interaction to take place, the teacher must provide students with the necessary time and space to get to know each other and exchange ideas. Some important cognitive activities and interpersonal dynamics can only be carried out when learners support each other face-to-face, i.e., through promotive interaction [12].

In order to minimize the negative effects that can occur at the beginning of each school year in associated with changes of teachers and new groups, it is advisable to articulate coordination mechanisms among teachers that allow them to manage concise information from the students about the functioning of CL in the previous year. Active pedagogies consider the student as the centre of the process, so it should be the teacher who adapts to the student's developmental process and not vice versa, as is the tendency in traditional methodologies.

Finally, the third hypothesis was confirmed; females scored higher than males, confirming that gender interacts positively with mathematics performance. These results are consistent with the results of previous research involving active methodologies. For example, it has been suggested that active methodologies are highly relevant to the gender equity of students in the learning of mathematics [23]. However, most research and reports on gender and mathematics performance indicate a considerable gender gap in favour of boys [51,52]. Recent international reports indicate a difference of eight points in favour of boys [53].

Therefore, it is possible that CL can help to channel equity in the learning of mathematics. In this regard, it has recently been suggested that CL provides the appropriate educational conditions to prevent the traditional gender gap in the performance of mathematics [54]. In the present study, females achieved improved results in mathematics after a CL implementation programme, confirming this hypothesis.

This research presents various strengths, including the longitudinal nature of the study. Recently, the importance of developing longitudinal studies on the implementation of CL has been suggested, given the scarcity of such studies in the scientific literature [23]. Likewise, the large size of the sample and the variety of educational stages analysed provide consistency and relevance to the study. Furthermore, the use of a validated survey on CL addresses the limitations of previous studies on the development, control and evaluation of this methodology. In this sense, the need to use validated instruments that include the basic elements of CL, such as those suggested by Johnson and Johnson, has been suggested [14].

5. Conclusions

The results of this study indicate that systematic and well-structured initial training is a determining factor for the correct implementation of CL. However, coordination strategies and control tools that ensure its continuity over time are necessary, especially in the context of changes between years and/or stages. In addition, our result show that the implementation of CL through the structured organisation of groups and cooperative techniques during a school year is related to improved performance in mathematics; however, the variables that intercede in changes of school year and/or educational stage, such as changes of teachers, could alter the effectiveness of this methodology. In this sense, additional longitudinal studies that consider these variables are needed. Finally, our analyses confirm that CL is a methodology that provides an equitable learning environment, reducing the gender gap that is traditionally produced in subjects such as mathematics. In conclusion, this study has important implications for the teaching of mathematics and sustainability, highlighting the emerging methodology of cooperative learning and showing lines of action for school management teams for its correct implementation.

However, this study is also subject to some limitations. On the one hand, the need for a quasi-experimental design did not allow for a control group. One the other hand, the variable of teacher change between grades or educational stages was not considered. Thus, the influence of teacher change on the effectiveness of CL in the same group of students in different school years is unclear. Previous research has highlighted the importance of the teacher in the correct implementation of CL and has suggested that when the teacher shares information and works cooperatively, better results are obtained [6]. Further longitudinal studies should be conducted to introduce new variables such as change of teacher and previous information that the new teacher receives about students' cooperative learning experience.

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