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Self-regulation of primary school teachers in initial training when solving mathematical problems in cooperative learning contexts

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ABSTRACT

The development of high levels of mathematical competence at an early age is a good predictor of academic success at higher levels of the education system. In this sense, the initial training of primary school teachers and, in particular, the achievement of high levels of self-regulation when solving mathematical problems is crucial to achieve this goal. The aim of this study is to evaluate the impact of a teaching-learning proposal based on the principles of cooperative learning on the level of self-regulation exhibited by primary education students when faced with mathematical problems. The study was carried out on a sample of 117 students in the first year of the University of the Basque Country's primary education degree using a scale validated for this purpose with good psychometric properties as an instrument for measuring levels of self-regulation. The results obtained show that the students' level of self-regulation improves significantly after implementation. Likewise, differences are observed from the perspective of the gender of the participants in relation to the attitude towards the statement of a mathematical problem and the ability to ask for help.

Keywords: self-regulation of learning, mathematical problem-solving, mathematics education, primary education grade, cooperative learning

INTRODUCTION

In today's society, characterized, among other things, by a high acceleration of changes affecting the generation and dissemination of new information and, most notably, technological development, mathematics learning and teaching should focus on developing students' ability to think critically, to behave autonomously, to solve problems creatively and to apply mathematical concepts in everyday, realistic situations (Darling-Hammond, 2017; Garcia, 2019; Schoenfeld, 2018).

From this perspective, the acquisition of adequate mastery of basic mathematical skills has become a priority objective and its importance and promotion is included as part of sustainable development goal 4.4 set by the United Nations Educational, Scientific and Cultural Organization (UNESCO, 2016).

However, the achievement of this objective seems distant, at least if we look at reports such as those emanating from international standardized assessment tests, as in the case of program for international dtudent assessment (PISA) 2022 (Ministry of Education and Vocational Training, 2023). Thus, a first glance at the results allows us to observe how, in the case of Spain and in terms of mathematical competence, students obtain an average score of 472, which is worse than in previous editions (482 in 2018). Although this is a negative figure, it is no less true that this deterioration is not very different from that suffered by most of the participating countries, apparently as a consequence of the educational impact of COVID-19. However, beyond this score, the report also shows serious shortcomings in the development of mathematical competence, as well as a worrying percentage of students in the lower levels, especially when compared to the percentage of students in the higher levels, which can clearly be improved.

In this context, it is recognized that, in order to contribute to the achievement of quality mathematics education, it is essential for teachers to have initial and continuing mathematics education (Casis et al., 2017; Garcia, 2019; Schoenfeld, 2018). However, it can be observed that pre-service teachers experience feelings of doubt and insecurity about didactic changes in their teaching practices (Burić & Frenzel, 2023; Hu et al., 2024). This can have a significant impact on students' learning and performance in mathematics.

Furthermore, research in mathematics education points to a set of underlying factors (motivational, affective, cognitive) that affect academic performance. Thus, negative attitudes and beliefs towards mathematics–particularly towards problem-solving–

as well as emotions and feelings that translate into anxiety, insecurity, frustration and distress are found (Chen & Lo, 2019; Marbán et al., 2021; Nortes Martínez-Artero & Nortes Checa, 2017). These factors that influence students' mathematics teaching and learning are also transmitted through instruction (Bates et al., 2011).

On the other hand, self-regulation of learning, a multidimensional construct referring to students' ability to regulate their own thoughts, emotions and behaviors to achieve a goal, is considered a key element for students' academic success (Bembenutty et al., 2015; Panadero & Alonso-Tapia, 2014; White & DiBenedetto, 2018).

Based on the scale adapted and validated in the study by Landa et al. (2024a), which provides a specific tool for measuring self-regulation in mathematical problem-solving contexts of primary school teachers in initial training, the aim of this study is to analyze, through a didactic proposal based on the principles of cooperative learning (CL), the evolution of the level of self-regulation of primary education students in mathematical problem-solving contexts.

THEORETICAL FRAMEWORK

Self-regulated learning refers to the ability of learners to control and direct their own learning process, which involves setting learning goals, selecting and applying effective strategies, maintaining motivation, managing time efficiently, monitoring their progress and evaluating their own performance (Zimmerman & Kitsantas, 2014).

From a socio-cognitive perspective in which we recognize that learning is not an isolated process but is influenced by social, emotional and cognitive factors, the present study is based on the self-regulation model proposed by Zimmerman (2002). This model divides the process of self-regulation into three cyclical phases: anticipation, execution, and self-reflection. In addition, it identifies critical dimensions that students must regulate. Thus, we have *motives*, which direct students towards the goals they wish to achieve, with two important aspects in this dimension being goals and self-efficacy. *Method* refers to how self-regulated learning occurs. Here, the key processes are the strategies and routines that each learner uses to learn effectively. In the *time dimension*, the self-regulated learner chooses when and for how long to engage in a specific task. Time management is a key process in this dimension. The *behavior dimension refers to the* outcomes or levels of competence that the learner wishes to achieve. Key self-regulatory processes in this dimension include self-observation, self-judgement and self-reaction. Finally, the *social environment* dimension focuses on the interactions and relationships with others that influence the learning process.

In addition to Zimmerman's (2002) model, which is widely recognized and used in educational research, this paper assumes Boekaerts' (1997) model, which includes key aspects of the research such as affective and domain-specific aspects. This holistic approach provides a solid basis for understanding how students regulate their own learning and achieve better academic results.

In this context, the study carried out by Fernández et al. (2013) with a sample of 552 first-year university students from different degrees at the University of Oviedo confirms that, in order for students to implement self-regulation strategies for learning, it is important that they feel capable of doing so, with self-efficacy for the use of self-regulation strategies for learning being the variable with the greatest predictive capacity in the use of these strategies. Thus, a poor sense of self-efficacy could be responsible for the academic problems of a large proportion of students (Usher & Schunk, 2018).

In the same vein, several studies suggest that self-regulation and motivational beliefs are significantly influenced by variables in the classroom environment (Velayutham & Aldridge, 2013; Wolters & Benzon, 2013), which is evident in the study by Rojas-Ospina and Valencia-Serrano (2021), which reveals that when students, at university level and in the area of mathematics, perceive a positive classroom climate, where the teacher promotes a safe environment for participation and communicates clear expectations to students about their performance, they show greater motivation in class, as well as greater self-efficacy, more interest in the content, more commitment and more effort.

On the other hand, CL is considered a solid and effective method for teaching mathematics at any school stage (Herrada & Baños, 2018). Numerous research studies, including a systematic review of cooperative dynamics carried out by Medina Bustamante (2021), conclude that this type of dynamics among students develops significant learning, interacting with their peers, with respect, leadership, autonomy and self-regulation. Key elements of this methodology are teamwork, understood in terms of collaboration and support from peers (Panadero & Alonso-Tapia, 2014) and individual commitment. Another of the contributions of this educational methodology is related to the improvement of motivation, self-efficacy and attitude (Desdentado et al., 2022), aspects that influence self-regulation and the mathematical problem-solving process.

Based on previous research on the benefits of CL, this research project proposes an educational proposal based on the principles of CL to analyze the possible impact that this proposal would have on the level of self-regulation of students in primary education.

METHOD

This is a quasi-experimental study aimed at gathering useful evidence on the effectiveness of a didactic proposal based on the principles of CL. The aim is to analyze whether this proposal causes a positive evolution in the levels of self-regulation of primary education students in mathematical problem-solving contexts.

Sample

A non-probabilistic convenience or incidental sample was used to select the sample, as the students who participated in the study were selected on the basis of their accessibility and suitability for the study.

Table 1. Sample data in the academic year 2022/2023

Variables	Academic year 2022/23	
	n = 117	Percentage (%)
Gender identity		
Female	84	72
Male	32	27
Non-binary	1	1
Baccalaureate mode		
Social sciences	80	69
Science and technology	36	31
Arts	1	1

Table 2. Distribution of items by factor

Factors	Items
Factor 1: Students' perception of their ability and how this influences the self-regulation of the resolution process	20, 21, 24, 28, 29, 30, & 31
Factor 2: Ethics	1, 2, 3, 4, 12, & 22
Factor 3: Problem solving and personal growth	33, 37, 38, 39, & 40
Factor 4: Attitude to the statement	5, 6, 7, 8, 9, 10, 11, & 15
Factor 5: Negative self-efficacy beliefs and external causal attribution	14, 16, 25, 32, 35, 36, & 41
Factor 6: Problem-solving method	17, 18, 19, 23, & 27
Factor 7: Social environment	13, 26, & 34

Note. The wording of the items can be found in **Appendix A**

The study involves 117 students in the first year of the primary education degree at the University of the Basque Country in the 2022/2023 academic year. The choice of incoming students is a relevant decision, as we wish to obtain information on their level of self-regulation at the beginning of their training and, in particular, before the students receive specific instruction on concepts and practices linked to the process of solving mathematical problems, a key area of the subject *didactics of mathematics* taught in the first year. The characteristics of the sample are detailed in **Table 1**.

Instrument

The instrument used in this study is a scale on self-regulation of learning in mathematical problem-solving contexts adapted for university students and duly validated (Landa et al., 2024a). The questionnaire consists of 41 items (see **Appendix A**) grouped into seven interrelated factors, but with their own factorial identity (see **Table 2**) and corresponds to a Likert scale with 7 response levels where 1 = never or almost never; 2 = about one in ten times; 3 = about one in three or four times; 4 = about 50% of the time; 5 = about two in three times; 6 = between eight and nine times in ten, and 7 = always or almost always.

Table 2 shows the items that make up each of the factors.

Procedure

The fieldwork is carried out in the second term while the students work, for four weeks, on the contents of the subject "solving mathematical problems" in a context of educational intervention based on the principles of CL. The study includes the synchronous online application of the scale through the Forms application with pre- and post-test measurements, i.e., before the didactic proposal, the students answer the online questionnaire (pre-test) and at the end of the intervention a new measurement is taken (post-test) in order to find out the progress achieved by the students in their level of self-regulation in this area. All of this, after the participating students had signed the corresponding informed consent form in which they were informed of the objective of the study and the procedure, as well as guaranteeing the privacy and confidentiality of the data of the participants and the rest of the ethical aspects inherent to a consent of this type. In both measurements, each student voluntarily answered the questionnaire, and the process was carried out in all cases without notable incidents, with the average time invested in the completion of the questionnaire being approximately 15 minutes.

Data Analysis

Data analysis was carried out using the SPSS 28.0 statistical program. First, a descriptive analysis was performed by calculating the means (M) and standard deviations (SD), at the general level of the scale and by factors, for both pre- and post-test. Inferential analysis is then carried out to assess whether there are significant differences between pre- and post-test. In each case, the assumptions of the general linear model (GLM), normality and homoscedasticity are checked; if the assumptions of the GLM are satisfied, the student's t test for dependent samples is applied and, if not, the Wilcoxon test is applied.

Secondly, inferential analysis is carried out to assess whether there are significant differences between groups according to the variables *gender identity* and *type of baccalaureate of origin*. In each case, the assumptions of the GLM, normality and homoscedasticity are tested; if the assumptions of the GLM are satisfied, student's t-test is applied and, if not, the Mann Whitney U-test is applied.

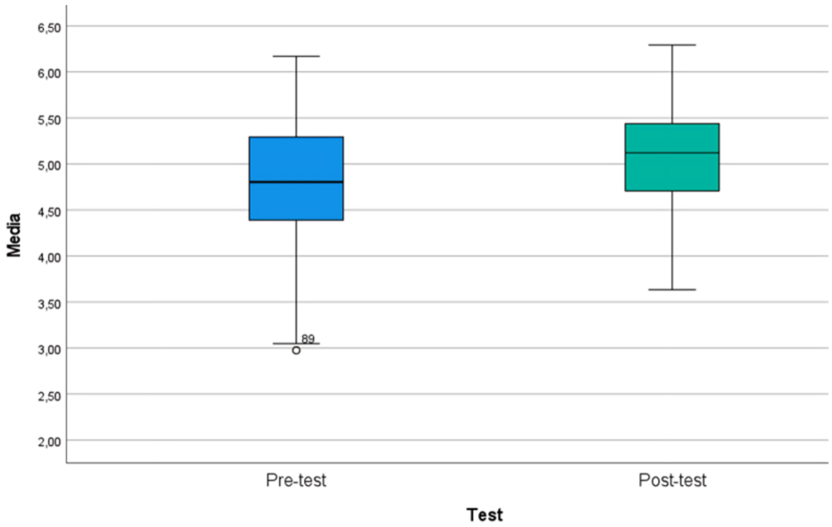

Figure 1. Pre- and post-test box plots (Source: Authors' own elaboration)

Table 3. Statistical values (*M* and *SD*) of the scale in the pre- and post-test

Test	N = 117	*M*	*SD*	Sig.	Cohen's d
Pre-test	117	4.8	.62	< .001	.455
Post-test	117	5.1	.53		

Table 4. Statistical values (*M* and *SD*) in the pre- and post-test of the highest scoring items

Item	Dimension	Pre-test		Post-test	
		M	*SD*	*M*	*SD*
- If I don't know how to do it myself, I find it important to learn from my peers.	AS	6.22	1.1	6.39	.93
- If I don't understand a statement I am able to ask for help to understand it.	AS	6.10	1.1	6.29	1.1
- If the statement is difficult to understand, I read it several times and try to understand it.	Ethics	6.14	1.2	6.21	.96
- If, after thinking about the problem for a long time, I am not able to solve it, I am able to ask for help from one of my classmates, teachers or people close to me.	AS	6.17	1.1	6.21	1.1

RESULTS

In order to give an overall idea of the results obtained on the scale, a variable, mean score, is defined, which refers to the average score obtained by each student. This can vary between 1 and 7, where 1 corresponds to the minimum level of self-regulation and 7 to the maximum level of self-regulation.

Figure 1 shows the box plots of the pre- and post-test. Fifty percent of the pre-test data are between 4.4 and 5.3 and the post-test between 4.7 and 5.5. Also, as can be seen from the size of the boxes, the dispersion of the data is also greater in the pre-test than in the post-test. Finally, in the pre-test there is one outlier, case 89, which, with a mean below 3.0 points, indicates that this person's level of self-regulation is very low; in contrast, no outliers are found in the post-test. In short, there is an increase in the number of students with higher means in the post-test compared to the pre-test.

As can be seen in **Table 3**, although the means obtained in the pre- and post-test are close, it is higher in the post-test. This difference is, in turn, statistically significant ($p = .001 < .05$), with a medium or moderate effect size (Cohen's $d = .455$).

In short, the didactic proposal significantly improves the level of self-regulation of primary education students in mathematical problem-solving contexts.

Next, we proceed to calculate the means and standard deviations for each item. It should be noted that the items with the highest means in both the pre- and the post-test belong to the "social environment" and "ethics" dimensions (see **Table 4**). In fact, the 3 items that make up factor 7, "social environment", had the highest values of the entire scale in both tests.

Therefore, in general terms, it can be observed that both in the pre- and the post-test, the pupils in the sample are mainly characterized by the fact that they tend to seek help from their social environment to overcome blocks or difficulties and, at the same time, they assume responsibility for the task, trying to solve the problem by their own means.

When analyzing the data by factors, it should be noted that, although all of them improve their scores after the didactic proposal, the differences between the pre- and post-test are significant in factors 1 ("students' perception of their ability and how this influences the self-regulation of the resolution process"), 2 ("ethics"), 4 ("attitude towards the statement") and 6 ("problem-solving method") (see **Table 5**).

Firstly, it should be noted that the teaching proposal based on the principles of CL significantly increases students' self-efficacy in the process of solving mathematical problems. This is reflected in factor 1, whose score increases notably in the post-test; in particular, the items ("I am able to sequence, describe and correct the steps taken to reach the solution") and ("I am able to see

Table 5. Statistical analysis (*M*, *SD*, significance, and effect size) in the pre- and post-test according to factors

Dimensions		Pre-test	Post-test	Sig.	Cohen's d
Factor 1	*M*	4.85	5.20	< .001	.383
	SD	.93	.80		
Factor 2	*M*	5.47	5.71	.013	.300
	SD	.79	.69		
Factor 3	*M*	4.55	4.72	.057	
	SD	.93	.79		
Factor 4	*M*	4.74	5.15	< .001	.472
	SD	.89	.77		
Factor 5	*M*	3.52	3.57	.665	
	SD	.8	.7		
Factor 6	*M*	5.28	5.66	< .001	.399
	SD	.9	.8		
Factor 7	*M*	6.17	6.3	.089	
	SD	.9	.9		

the possibilities of my solution to extend it to other problems") show significant progress, obtaining results above the overall average for this factor after implementation (see **Appendix B**). Likewise, the item "I prefer challenging tasks (therefore a bit more difficult and adventurous) to exercises where I know exactly what I have to do" refers to aspects of motivation and also improves significantly from the pre-test (M = 3.8; SD = 1.8) to the post-test (M = 4.4; SD = 1.7).

This is followed by factor 2: "ethics", which also shows significant progress in the post-test, i.e., students, after implementation, show greater commitment to the problem-solving task and greater persistence in the search for solutions. Thus, for example, the items ("I give up reading a problem as soon as its statement is longer than 5 lines") and ("I tend to keep the habit of spending time to understand the problems"), which are related to perseverance, improve significantly after the didactic proposal (see **Appendix A**). Further evidence in this sense is provided by the following item "If the statement is difficult to understand, I read it several times and try something to understand it", which obtains one of the highest scores on the scale, occupying third place in the overall list of items (see **Table 4**).

The didactic proposal also contributes significantly to the improvement of the score in factor 4: "attitude towards the statement" being the factor that reaps the highest effect size of the whole scale (Cohen's d = .5). This positive result reveals that such a proposal helps to improve students' attitude towards understanding and approaching mathematical problem statements. An example that points in this direction is the item "If I don't understand the statement I talk to myself to try to understand it" which obtains moderate data in the pre-test (M = 4.7; SD = 1.2) and registers a notable improvement in the post-test (M = 4.7; SD = 1.2).

Factor 6: "Problem-solving method" is another factor that shows significant progress in the post-test. This progress is manifested, among others, in the items ("I am able to express my provisional conclusions about the solution (conjectures) even though I am embarrassed to express them") and ("I am able to be critical of myself, questioning the steps of my solution"), which show significant differences between the pre- and post-test (see **Appendix B**).

On the other hand, although factor 3 as a whole has not improved significantly after the didactic proposal, it is interesting to note that there are significant differences in the item "when I solve problems I am so concentrated that it is as if time stops", obtained in the pre-test (M = 4.4; SD = 1.6) and in the post-test (M = 4.8; SD = 1.4), which suggests that working cooperatively in a team increases concentration and time spent solving mathematical problems. Although this specific change is not sufficient to significantly affect the factor as a whole, it adds evidence to the above (see **Appendix B**).

The same occurs with factor 5: "negative self-efficacy beliefs and external causal attribution" which, as a whole, does not show a significant improvement after implementation, however, significant differences are found in the following item "the main person responsible for my getting into trouble is the teacher", with the score obtained in the pre-test (M = 4.6; SD = 1.3) and post-test (M = 5.0; SD = 1.3) (see **Appendix B**).

Finally, factor 7: "social environment" does not improve significantly after implementation, despite the fact that its component items obtain the highest scores in the post-test (see **Table 4**). This is because the factor was already highly rated in the pre-test, with scores above 6 in all its items, and therefore there was little room for improvement in this factor.

Results According to Gender Perspective

Next, the means and standard deviations are calculated, both for the pre- and post-test, according to the gender identity variable. Inferential analysis is also carried out to assess whether there are significant mean differences, before and after the didactic proposal, in this demographic variable.

Firstly, as can be seen in **Table 6**, for both females and males the difference in means between the pre- and post-test is statistically significant, with a medium to moderate effect size in both sub-samples (Cohen's d = .5).

Therefore, the didactic proposal significantly improves the level of self-regulation of primary education students in mathematical problem-solving contexts, regardless of gender identity.

Secondly, the means obtained by women and men are close and, although being higher in women, the differences are not statistically significant either in the pre-test ($p = .392 > .05$) or in the post-test ($p = .083 > .05$). When analyzing the evolution of the mean differences between men and women, no significant differences were found either ($p = .249$).

Table 6. Statistical analysis (*M*, *SD*, significance and effect size) in the pre- and post-test according to gender perspective

Gender identity		Pre-test	Post-test	Sig.	Cohen's d
Female (84)	*M*	4.84	5.12	< .001	.468
	SD	.64	.53		
Male (32)	*M*	4.73	4.93	.008	.449
	SD	.55	.498 (.5)		

Table 7. Statistical analysis (*M*, *SD*, significance, and effect size) in the pre- and post-test according to gender perspective

Gender identity	Factor 1				Factor 4				Factor 7			
	Pre-test		Post-test		Pre-test		Post-test		Pre-test		Post-test	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Female (84)	4.8	.96	5.2	.82	5.12	.88	5.3	.75	6.4	.63	6.44	.84
Male (32)	5.0	.88	5.2	.76	4.83	.83	4.8	.74	5.6	1.24	5.94	1.03
Sig.	.241		.452		0.11		.004		< .001		.009	

Table 8. Statistical analysis according to baccalaureate mode

Baccalaureate mode		Pre-test	Post-test	Sig.	Cohen's d
Humanities and social sciences (80)	*M*	4.73	5.05	< .001	.568
	SD	.65	.55		
Science and technology (36)	*M*	4.98 (5)	5.08	.116	
	SD	.5	.47		

Therefore, the gender identity variable is not a determining factor in the level of self-regulation of primary education students in mathematical problem-solving contexts, i.e., it cannot be affirmed from the results obtained that women have a more positive level of self-regulation towards the task of solving mathematical problems than men, neither before nor after the didactic proposal.

However, when analyzing the results by factors, in the post-test, significant differences are found in two of them, factor 4: "attitude towards the statement" and factor 7: "social environment", with women obtaining higher scores than men (see **Table 7**). From this result it can be seen that, after the implementation, women significantly improve their attitude towards the statement of a problem, compared to men, and also have a greater willingness to seek help in their environment. It should be noted that in this demographic variable, no significant differences are found in factor 1: "students' perception of their ability and how this influences the self-regulation of the resolution process" (see **Table 7**). This result is not in line with that obtained in previous studies (Landa et al., 2024b) where the level of self-efficacy is higher in males than in females.

Results According to the Type of Baccalaureate

In this section, we calculate the means and standard deviations of both the pre- and the post-test, according to the baccalaureate mode variable. We also proceed to the inferential analysis to assess whether there are significant differences in means, before and after the didactic proposal, in this demographic variable.

As can be seen in **Table 8**, in the pre-test, the mean obtained in science and technology is higher than in humanities and social sciences. The inferential analysis also indicates that the difference in means between the baccalaureate modalities is significant ($p = .004 < .05$).

Therefore, the chosen mode in baccalaureate is a factor that operates in the level of self-regulation in mathematical problem-solving contexts, where students who choose the science and technology mode have a higher level of self-regulation in the process of solving mathematical problems than the rest of the baccalaureate modes.

In this section, and in view of the results, it is worth noting that students whose baccalaureate is science and technology do not register significant mean differences between the pre- and the post-test, i.e., the didactic proposal does not operate in this group of students.

On the other hand, in the Humanities and social sciences modality, the difference in means between the pre- and the post-test is significant, with the highest effect size value (.6) of the study. Therefore, the didactic proposal significantly improves the level of self-regulation of students belonging to this modality of baccalaureate in contexts of mathematical problem-solving.

Finally, the inferential analysis shows that, after the didactic proposal, the mean differences between the two modalities are not significant ($p = .410 > .05$).

DISCUSSION AND CONCLUSIONS

The level of self-regulation, in general terms, of future primary school teachers in mathematical problem-solving contexts has improved significantly after the teaching proposal based on the principles of CL, which is a sign of its success.

This global result adds evidence to what is indicated in the theoretical framework on the convenience of using CL to improve the level of self-regulation (Medina Bustamante, 2021; Saimun et. al, 2019) of primary education students in mathematical problem-solving contexts (Herrada & Baños, 2018).

A more in-depth analysis of the scale, at the level of factors, shows that the didactic proposal has a significant influence on four of them; thus, it increases students' self-efficacy in problem-solving, promotes greater assumption of responsibility by students, improves their attitude to the problem statement and shows improvements in both the choice of strategies and the efficiency of the processes used.

First, the improvement of self-efficacy through CL in mathematics is supported by previous studies (Fernández-Río et al., 2023; Johnson & Johnson, 2018), therefore, the achievement of this research in relation to the increase of students' perception of their ability to solve mathematical problems is consistent with previous findings.

This result is particularly relevant since, according to Sánchez-Mendías et al. (2020), most primary school students do not have sufficient confidence in their mathematical skills, which is crucial for their professional development and for promoting a positive attitude towards mathematics in their teaching practice. Consequently, it is necessary for future teachers to increase their self-confidence in order to avoid promoting negative attitudes towards mathematics in the classroom (Sánchez-Mendías et al., 2020).

Ethics, understood as the responsibility with which each student consciously and fully accepts the task of solving the problem, seeking objectives with perseverance, patience and through their own means (Marbán & Fernández-Gago, 2022) is another key element of self-regulation and, as seen in the results, it improves significantly through CL, which demonstrates a positive contribution of this methodology in relation to the constancy and commitment of students to the problem-solving task. From this perspective, students show a greater willingness to take responsibility for their own learning and effort, rather than attributing success or failure to external agents such as luck or teacher assistance, which is positive for their academic development.

On the other hand, several studies (Nortes Martínez-Artero & Nortes Checa, 2017; Tsao, 2014) show that the attitude of primary school students towards mathematics is slightly positive; this is confirmed in our study where the students' attitude towards the statement of a mathematical problem, before implementation, although positive, is moderate. However, after implementation, this key aspect of self-regulation improves significantly, which adds further evidence to the success of the implementation since, according to Pedrosa-Jesús et al. (2020), it is of utmost importance to examine the attitudes towards mathematics of future primary education teachers due to the influence they have on the teaching of the subject.

Furthermore, factor 6: "solving method" also shows significant progress after implementation, confirming that the didactic proposal contributes positively to students using more effective strategies and developing more efficient processes to approach and solve mathematical problems.

These achievements are consistent with those obtained in research such as that of Sánchez and Casal (2016) on the development of autonomy, where it is concluded that through CL techniques, students experience satisfaction when seeking and finding strategies to achieve the proposed goals, which helps them to better understand their strengths and weaknesses, as well as to interact with others, assuming positive attitudes. It should be noted that this improvement in attitude is part of the idea of learning, which according to Sáez López (2018) is considered as the process in which information is assimilated and a change in behavior is observed.

In relation to the gender identity variable, the level of self-regulation in women increases positively and significantly after the didactic proposal based on CL principles. This result confirms that obtained in other previous research studies such as that of Macho et al. (2021) where, after analyzing relevant studies on classroom experiences, it is concluded that women learn better in environments where there is a climate of cooperation rather than competitiveness.

On the other hand, there are no significant differences between men and women, neither before nor after implementation, and although women score higher and this difference increases after the educational proposal, it is not significant.

However, when analyzed by factors, after implementation, significant differences are found with respect to the gender perspective in factors 4 ("attitude towards the statement") and 7 ("social environment"), with both aspects being more positive in women than in men.

The achievement with respect to factor 4: "attitude towards the statement" is striking as it is not in line with other studies on record (Hill & Bilgin, 2018; Pedrosa-Jesús et al., 2020) where the attitude towards mathematics of primary school students is more positive in males than in females.

The result in relation to factor 7: "social environment" adds evidence to studies cited in the theoretical framework where it is noted that females tend to ask for help to a greater extent than males in case of difficulty in mathematics (Gasco-Txabarri, 2017; Virtanen & Nevgi, 2010).

On the other hand, although men, before implementation, obtain a higher score than women in factor 1: "students' perception of their ability and how this influences the self-regulation of the resolution process", it does not reach statistical significance. In fact, this difference decreases after the educational intervention, with the means of males and females becoming equal. This result is particularly noteworthy given that research such as that of Mego-Sánchez et al. (2020) finds that females have lower levels of mathematical self-efficacy than males.

In relation to the variable baccalaureate mode, the difference is significant before the proposal, with a higher level of self-regulation in the science and technology mode. However, after the didactic proposal, the level of self-regulation in Humanities increases and there are no significant differences between the different modalities. Therefore, in this research, the didactic proposal based on the principles of CL has contributed to levelling the level of self-regulation among students from different modalities of the baccalaureate.

In short, although the teaching proposal based on co-operative learning principles improves the level of self-regulation of future primary school teachers, there is still room for improvement. To this end, it would be interesting to see which factors or items do not show significant progress. In this sense, Landa et al. (2024c) conclude that factor 1: "students' perception of their ability and how this influences the self-regulation of the resolution process" acts as a moderating variable, influencing the level and direction of the relationship between self-regulation and problem-solving. Consequently, it would be possible to analyze in what sense and in what way this factor impacts on the rest of the factors of the scale in order to be able to adapt future interventions according to the needs and individual characteristics of the students, which could lead to more effective and personalized results.

Finally, neither males with regard to the attitude of the statement nor students whose baccalaureate mode is science and technology experience improvement after the didactic proposal in the classroom. Therefore, future research should consider these findings, which highlight the importance of considering differences in both gender identity and baccalaureate mode when designing educational interventions and providing additional support according to the specific needs of each group.

In summary, it is confirmed that the didactic proposal improves the level of self-regulation of future primary education teachers. However, like all research work, this is not without its limitations. One of them may be the limited duration of the didactic proposal, only 4 weeks. Future research could carry out CL experiences of longer duration in order to better understand the long-term effects of this methodology on pupil development.

In addition, the evolution of the students' level of self-regulation is based on the answers provided by means of a questionnaire administered before and after the implementation of the didactic proposal. To enrich these results, it would be beneficial to complement this quantitative approach with others of a qualitative nature, such as semi-structured interviews with students or direct observation of their attitudes in the classroom. The combination of both methods would provide a more solid basis for the interpretation of the results and would allow for a more complete and deeper understanding of the changes in the level of self-regulation of primary school students.

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APPENDIX A

Table A1. Questionnaire on self-regulation of learning in problem-solving contexts

Original coding	Current recoding	Statement
1	1	I stop reading a problem as soon as the problem statement is more than 5 lines long.
2	2	If the statement is difficult to understand, I read it several times and try to understand it.
4	3	Even if a problem statement makes me unsure, I try to solve the problem.
5	4	When I try to understand a problem, even if I have doubts, I don't give it up because I take responsibility for solving it.
6	5	After reading a problem statement I highlight or represent the essential conditions or information of the problem.
8	6	If I don't understand the statement I talk to myself to try to understand it.
9	7	If I feel insecure when I read a statement, I have resources to feel more confident.
10	8	As I'm reading, I encourage myself by reminding myself that understanding the statement depends on what I try and how I try.
11	9	If I have failed to understand a statement, I try to look for the causes so that the same thing does not happen to me the next time.
12	10	Even if a problem seems useless or uninteresting to me, before I start to solve it, I try to motivate myself by reminding myself how important it is to learn it in order to pass the exam and the subject, and thus finish the course, the degree,…
13	11	If I have understood the statement of a problem, I look at what worked for me in order to repeat or improve it in the next problem.
14	12	I tend to keep in the habit of taking time to understand the issues.
15	13	If I don't understand a statement I am able to ask for help to understand it.
16	14	If I have a fixed idea of how to solve the problem I am not able to change it.
17	15	After understanding the statement I think of different strategies to deal with it (try examples, start with simpler cases, change the statement, look for similar problems, look for regularities, etc.).
18	16	After a while of weighing up plans, I'm not usually clear about which one I'm going to choose.
19	17	Before writing a tentative conclusion about the solution (conjecture) I think about whether it makes sense.
20	18	I am able to express my tentative conclusions about the solution (guesses), even if I don't know if they are right.
21	19	I am able to express my tentative conclusions about the solution (conjectures) even though I am embarrassed to express them.
22	20	At all times I know what I am doing on a problem, what I am doing it for and how what I am doing is useful for the solution.
23	21	If, after overcoming a difficulty, another difficulty arises in the problem, I look for ways to overcome it myself.
24	22	I persist in pursuing my plan or idea, even if I am not sure if it is right.
25	23	I check my tentative conclusions (conjectures) or results to see if they are consistent or if the conditions of the statement are met.
26	24	I am able to control my emotions while solving a problem.
27	25	If, when I check a solution, I realize that it is wrong, I am not able to take advantage of what is right to look for another way.
28	26	If, after thinking about the problem for a long time, I am not able to solve it, I am able to ask for help from one of my classmates, teachers or people close to me.
29	27	I am able to be critical of myself, questioning the steps of my solution.
30	28	I am able to sequence, describe and correct the steps taken to reach the solution.
31	29	I am able to see the possibilities of my solution to extend it to other problems.
32	30	I am able to take an interest in other solutions and see the advantages or disadvantages with my own.
33	31	I prefer challenging tasks (therefore a bit more difficult and adventurous) to exercises where I know what I have to do.
34	32	I don't engage in challenges that cause me fear, or stress or frustration or any negative emotions.
35	33	I find it important when solving problems to do it myself.
36	34	If I don't know how to do it myself, I find it important to learn from my peers.
37	35	I am not the one primarily responsible for solving the problem.
38	36	The main person responsible for the problem is the teacher.
39	37	I am capable of thinking, even for a week, about a problem that has not come up.
41	38	When I solve problems I am so focused that it is as if time stands still.
42	39	I believe that being responsible and putting all interest in solving problems is not only beneficial for me, but also for parents, teachers and classmates.
43	40	I think it is important that a problem is difficult in order to improve my education and to grow as a person.
44	41	If the problem is difficult, I am not able to generate positive emotions for its resolution.

APPENDIX B

Table B1. Factor 1

Number of items		Pre-test		Post-test
Item 20	*M*	4.65		4.96
	SD	1.40		1.30
	Sig.		.014	
Item 21	*M*	5.42		5.53
	SD	1.20		.90
	Sig.		.177	
Item 24	*M*	4.74		5.03
	SD	1.60		1.40
	Sig.		.052	
Item 28	*M*	5.21		5.56
	SD	1.20		1.10
	Sig.		< .004	
Item 29	*M*	4.85		5.35
	SD	1.14		1.10
	Sig.		< .001	
Item 30	*M*	5.25		5.55
	SD	1.20		1.10
	Sig.		.013	
Item 31	*M*	3.81		4.41
	SD	1.80		1.70
	Sig.		.001	

Table B2. Factor 2

Number of items		Pre-test		Post-test
Item 1	*M*	5.72		6.16
	SD	1.60		1.10
	Sig.		.013	
Item 2	*M*	6.14		6.21
	SD	1.18		0.96
	Sig.		.754	
Item 3	*M*	5.67		5.83
	SD	1.31		1.08
	Sig.		.229	
Item 4	*M*	5.28		5.42
	SD	1.36		1.28
	Sig.		.103	
Item 12	*M*	4.98		5.51
	SD	1.37		1.07
	Sig.		< .001	
Item 22	*M*	5.06		5.10
	SD	1.10		1.12
	Sig.		.822	

Table B3. Factor 3

Number of items		Pre-test		Post-test
Item 30	*M*	5.03		5.13
	SD	1.29		1.64
	Sig.		.575	
Item 33	*M*	5.65		5.60
	SD	1.21		1.14
	Sig.		.824	
Item 37	*M*	2.89		3.02
	SD	1.68		1.65
	Sig.		.384	
Item 38	*M*	4.35		4.79
	SD	1.60		1.43
	Sig.		.010	
Item 40	*M*	4.85		5.07
	SD	1.36		1.17
	Sig.		.062	

Table B4. Factor 4

Number of items		Pre-test		Post-test
Item 5	*M*	4.62		4.86
	SD	1.38		1.27
	Sig.		.055	
Item 6	*M*	4.70		5.77
	SD	1.21		1.09
	Sig.		< .001	
Item 7	*M*	4		4.37
	SD	1.49		1.39
	Sig.		.008	
Item 8	*M*	4.68		5.05
	SD	1.63		1.35
	Sig.		.015	
Item 9	*M*	4.88		5.21
	SD	1.52		1.23
	Sig.		.013	
Item 10	Sig.	4.85		5.02
	M	1.68		1.54
	SD		.172	
Item 11	Sig.	5.21		5.56
	Sig.	1.42		1.14
	M		.002	
Item 15	*SD*	5.01		5.38
	Sig.	1.42		1.19
	Sig.		.004	

Table B5. Factor 5

Number of items		Pre-test		Post-test
Item 14	*M*	3.09		3.41
	SD	1.38		1.31
	Sig.		.058	
Item 16	*M*	3.30		3.42
	SD	1.49		1.27
	Sig.		.578	
Item 25	*M*	3.44		3.32
	SD	1.56		1.57
	Sig.		.577	
Item 32	*M*	2.93		2.85
	SD	1.54		1.5
	Sig.		.723	
Item 35	*M*	3.32		3.09
	SD	1.57		1.58
	Sig.		.253	
Item 36	Sig.	4.62		5.01
	M	1.33		1.34
	SD		.008	
Item 41	Sig.	3.94		3.86
	Sig.	1.43		1.38
	M		.577	

Table B6. Factor 6

Number of items		Pre-test	Post-test
Item 17	*M*	5.63	5.83
	SD	1.30	1.09
	Sig.	.117	
Item 18	*M*	5.01	5.58
	SD	1.24	1.03
	Sig.	< .001	
Item 19	*M*	4.80	5.37
	SD	1.43	1.30
	Sig.	< .001	
Item 23	*M*	5.68	5.79
	SD	1.27	1.08
	Sig.	.484	
Item 27	*M*	5.30	5.70
	SD	1.26	1.02
	Sig.	.002	

Table B7. Factor 7

Number of items		Pre-test	Post-test
Item 13	*M*	6.10	6.29
	SD	1.08	1.13
	Sig.	.082	
Item 26	*M*	6.17	6.21
	SD	1.10	1.10
	Sig.	.703	
Item 34	*M*	6.22	6.39
	SD	1.07	.93
	Sig.	.157	