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Moderating Effect of Perceived Self-Efficacy on University Students'Self-Regulation in Mathematics Problem Solving

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Abstract

Self-regulation of learning is a complex and multidimensional construct and is recognised as a potential predictor of academic achievement in mathematics. The aim of this study is to create and interpret a structural equation model to test whether the perception of self-efficacy is particularly determinant in the level of self-regulation of primary school initial trainers in mathematical problem solving. For this purpose, a sample of 402 students from the first-year course of a Primary Education Undergraduate Degree at University of the Basque Country (UPV/EHU) was used. The results show that the seven identified factors are coherently related to key aspects of self-regulated learning in the context of mathematical problem solving. Similarly, it was confirmed that the perception of self-efficacy functions as a moderator in the level of self-regulation of students of a Primary Education Undergraduate Degree in mathematical problem-solving contexts.

Keywords Self-regulation · Mathematical Problems · Self-efficacy · Moderation · University

Introduction

The acquisition of adequate mastery of basic mathematical skills has become a priority objective in many education systems worldwide 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). Accordingly, it is recognised that, in order to contribute to the achievement of such a goal, it is essential that teachers have a solid and effective initial and continuous mathematical didactic training when designing their pedagogical action. Such

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training should enable students to develop their ability to think critically, to conduct themselves autonomously, to solve problems creatively and to apply mathematical concepts in everyday and realistic situations (Darling-Hammond, 2017; Schoenfeld, 2018).

However, research such as TEDS-M 2012 (International Study on Initial Teacher Education in Mathematics) shows, in the case of Spain, overall scores below the OECD (Organization for Economic Co-operation and Development) average in mathematical and didactic-mathematical knowledge on the part of teachers in initial teacher training (Tatto et al., 2013). Beyond the score itself, the study also reveals certain shortcomings that could have a significant impact on student learning and performance in mathematics (Döhrmann et al., 2014). Specifically, students obtained results below the international average in assessments such as PISA 2018 (Programme for International Student Assessment) (OECD, 2019) or TIMSS 2019 (Trends in International Mathematics and Science Study) (College, 2020). PISA 2022 results confirmed that this situation is getting worse; in mathematics, the level in Spain dropped 15 points between 2018 and 2022 (OECD, 2023).

Various research projects in the field of Mathematics Education point to a set of underlying factors (motivational, affective and cognitive) that affect academic performance. Thus, negative attitudes and beliefs towards mathematics—particularly towards problem solving—are found, as well as emotions and feelings that translate into anxiety, insecurity, frustration and distress (Gamboa Araya & Moreira-Mora, 2016; Caballero et al., 2016; Chen & Lo, 2019; Luttenberger et al., 2018; Nortes Martínez-Artero & Nortes Checa, 2017). These factors, which influence students'mathematics teaching and learning, are also transmitted through instruction (Bates et al., 2011; Sakiz et al., 2012). Further, socio-cognitive theories place as a key element for students'academic success their ability to self-regulate their own learning (Hadwin et al., 2017; Rosário et al., 2014; White & DiBenedetto, 2017). Similarly, motivational variables in self-regulated learning are increasingly being highlighted in the literature, underlining their role as crucial elements of academic success at school (Zimmerman & Schunk, 2011). Moreover, models of self-regulated learning have focused on self-efficacy as a fundamental motivational variable in the development of self-regulated learning (Panadero, 2017; Winne & Hadwin, 2008).

In this context, it should be noted that there are already works that offer a specific measurement tool for assessing self-regulation in mathematical problem-solving contexts, such as the scale designed by Fernández-Gago and Marbán (2022) for secondary school students. Taking this as a starting point, but focusing our interest on primary school initial trainers, the tool developed by Landa et al. (2024) is a scale that has good psychometric properties in terms of internal consistency and construct validity. In addition, a detailed exploratory factor analysis (EFA) suggests that the seven-factor structure is adequate for measuring self-regulation in the context of mathematical problem solving (Landa et al., 2024). Following on from this study, while the EFA helps to identify how items are grouped into factors or dimensions, it does not shed light on how these factors relate to and affect each other. In this sense, the structural equation model (SEM) is particularly useful to address these relationships and provide a more complete and in-depth view of the learner's self-regulation process. For example, the interactions between self-efficacy, self-judgement, attitudes and emotions towards mathematical problem solving can be examined; it is also possible, through the SEM, to identify patterns and determine which factors have a greater impact on self-regulated learning, enabling efforts to be better focused and allowing more effective educational interventions to be designed. The aim of this study is therefore to create and interpret a structural equation model in relation to the self-regulation of learning in mathematical problem-solving contexts carried out with primary school initial trainers that overcomes the limitations of the aforementioned EFA, in order to understand the statistical relationships between the theoretically defined factors and thus be able to gain a more in-depth understanding of the complexity of the model.

Theoretical Framework

Self-regulation of learning has been the subject of much research (Velayutham et al., 2011; Winne, 2010; Zimmerman, 2008) and is recognised as a determinant of academic success at all levels of education, including university level (Dent & Koenka, 2016; Harding et al., 2019; Zimmerman & Kitsantas, 2014).

This study is conceptualised from a socio-cognitive perspective, which addresses both cognitive and social aspects of self-regulation, providing a more holistic understanding of the construct of self-regulated learning. This approach is fundamental to understanding how students regulate their own learning and achieve better academic outcomes (Usher & Schunk, 2017). From this perspective, the self-regulation model proposed by Zimmerman (2002) is one of the most widely used in research and it is this model which guides the development of this paper. The work also takes into account Boekaert's model (Boekaerts, 1997) for integrating important aspects such as affective and domain-specific aspects, both crucial in the learning of mathematics and in mathematical problem solving.

According to Zimmerman's model, self-regulated learning is a cyclical process composed of three phases: (1) Phase of anticipation: in this initial phase, learners focus on preparing for learning by assessing their level of interest and motivation towards the task, analysing the task, setting learning goals and planning the strategies necessary to achieve those goals. (2) Phase of execution: during this phase, learners monitor themselves to ensure that they are following their plan and taking the necessary actions to progress towards their goals. (3) Phase of self-reflection: in this stage, learners reflect on their own performance and, after evaluating the quality of the task, may adjust their learning process, such as modifying strategies or setting new goals.

Another relevant aspect of Zimmerman's model are the dimensions (motives, method, time, behaviour, physical environment and social environment) which refer to what needs to be regulated in learning: with key processes being set within each dimension that enable these to be acted upon, an essential factor for achieving successful learning. Thus, we have *motives*, which direct the learner towards the goals they wish to achieve, with goals and self-efficacy being two important aspects in this dimension. *Method,* on the other hand, indicates how self-regulated learning occurs.

Here, the key processes are the strategies and routines that each learner uses to learn effectively. *Time* is a dimension where the learner chooses when and for how long to engage in a specific task. Time management is a key process in this dimension. *Behaviour* refers to the outcomes or levels of competence that the learner wishes to achieve. Key self-regulatory processes in this dimension include self-monitoring, self-judgement and self-reaction. In addition to these dimensions, Zimmerman also considers the *physical environment* and the *social environment*. The first refers to how the physical environment is structured to facilitate self-regulated learning. The second points to the interactions and relationships with other people that influence the learning process (Zimmerman, 2002).

Self-efficacy beliefs relate to students'confidence in their abilities to cope with academic challenges; according to Cleary and Kitsantas (2017), students'belief that they will succeed at a task directly influences their decision to engage and persevere in their learning, and is a significant predictor of academic performance. Self-efficacy is considered a fundamental variable (Yang et al., 2024) that affects both motivation and the learning process and, therefore, strengthening students'self-efficacy can have a significant impact on their academic performance and adaptation to the educational context, which makes it a relevant area for future interventions and educational approaches (Van Dinther et al., 2011). In this context, motivation and behaviour, dimensions of Zimmerman's model, are flexible, i.e., they can be changed and improved through instruction (Cleary & Kitsantas, 2017).

As noted above, among the processes of self-regulation, self-judgement is of particular importance. This is generated after the task and involves two sub-processes: self-assessment and causal attribution. On the one hand, the learner, in order to feel successful in self-assessment, must have fulfilled the requirements of the task and feel competent. On the other hand, causal attribution refers to the tendency of students to explain or attribute the causes of the results they experience in academic tasks. When students attribute success or failure to causes such as personal effort, perseverance and planning, their motivation increases and their academic performance is high, whereas if they attribute them to, among others, causes such as luck, the difficulty of the task, the teacher or poor ability, then motivation decreases and their academic performance is low (Dunn et al., 2012; Fernández et al., 2015).

In addition, self-judgement involves emotional responses that learners assign to outcomes and, depending on how these are perceived, determine the cause of the outcomes (Dunn et al., 2012). Specifically, self-judgement can significantly influence the interpretation of and response to the learning task, which in turn can affect future self-regulatory behaviours (Cleary et al., 2012).

In summary, self-regulation is a complex and multidimensional construct, understood or conceptualised as an active process in which learners set goals that guide their learning, attempting to regulate and control their cognition, behaviour, emotions and motivation with the intention of achieving said goals (Zimmerman & Kitsantas, 2014).

Restricting our interest to self-regulated learning and mathematical problem solving, we find several research studies that address this issue. Thus, a study by Cleary and Chen (2009) analyses the level of performance in mathematics, as well as differences in self-regulation and motivation, on a sample of 880 students at an intermediate level of education. One of the key findings of this study is that, as students progress through their education, they show a reduced ability to regulate their own learning as well as a less favourable motivation towards mathematics, which may in turn have a negative impact on their performance. Furthermore, the study finds that the main predictor of the use of regulation strategies during mathematics learning is interest in the task.

In Throndsen's (2011) study of primary school pupils at different levels, the relationships between mathematical skills, the use of metacognitive strategies and motivational beliefs are investigated. The results of the analysis reveal that students who perform well in mathematics not only use appropriate strategies to solve problems, but also demonstrate metacognitive skills, attribute their success to their own effort and have a high perception of self-efficacy.

In this sense, the research by Martínez Vicente and Valiente Barroso (2019) also shows that good performance in mathematics is not only associated with the use of strategies, but also with metacognitive competence, attributing success to effort and having a high perception of self-efficacy. As in other studies, the self-regulation and motivation profile is found to be more maladaptive as the educational level increases.

In the work of Zalazar-Jaime et al. (2011), self-efficacy in mathematics is defined as the value judgement that students generate concerning their ability to perform activities and tasks in some areas of mathematics. According to a recent study by Morán-Soto and Benson (2024), mathematical self-efficacy and mathematics anxiety influence the academic performance of university students. As a relevant aspect of specific self-efficacy in mathematics, the study by Calzadilla-Pérez et al. (2018) refers again to self-evaluation, a basic component of the self-judgement that affects the perception that students have of themselves. This is an aspect that, together with affective, emotional and physiological elements, develops self-efficacy beliefs in this subject (Bandura, cited in González-Franco et al., 2022).

In short, motivational beliefs are influenced by aspects such as self-efficacy, outcome expectancies, interest and goals, all of which are closely related to success in mathematics (Cleary & Kitsantas, 2017; Yang et al., 2024).

In particular, in the context of mathematical problem solving, current models of self-regulation of learning recognise the importance of motivational and emotional processes (Efklides, 2011; Tzohar-Rozen & Kramarski, 2017). In this regard, the study by Schoenfeld (2016) is crucial and emphasises the importance of students'resources, metacognitive strategies, beliefs and affect in the context of mathematical problem solving. In turn, Zimmerman's (2002) model also takes into consideration students'beliefs.

In summary, a greater capacity for self-regulation is associated with better mathematical problem solving, providing students with skills that help them to understand more deeply the problem to be tackled, to enable them to choose and use appropriate strategies at each moment, set quality objectives, and manage time and eventualities appropriately; in addition, self-regulation contributes to a better control of emotions during the process of solving mathematical problems (Zimmerman, 2002; Zimmerman & Kitsantas, 2014).

As demonstrated above, there are several studies that provide evidence on the importance of motivational beliefs such as perceived self-efficacy in relation to self-regulation in learning and mathematics. However, there are not many studies which focus on the factors involved in self-regulation in mathematical problem-solving contexts and, more specifically, multifactorial studies on self-regulation in the mathematical problem-solving process in the context of teacher education are few and far between.

The main objective of the present study is to contrast, using a structural equation model, the influence that the perception of self-efficacy has on relevant factors of self-regulation in the mathematical problem-solving process in the context of students taking an Undergraduate Degree in Primary Education.

Method

In view of what has been pointed out so far, it is essential to be aware of the level of self-regulation of future teachers in mathematical problem-solving contexts. The instrument designed for this purpose for secondary school students (Fernández-Gago & Marbán, 2022) and the one designed for university students (Landa et al., 2024) are taken as references from previous studies, the aim of this study being, as already indicated, to create and interpret a structural equation model associated with the latter group.

Study Design

The research is based on a non-experimental, cross-sectional approach.

Sample

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

A total of 402 students from the first-year course of a Primary Education Undergraduate Degree from the three campuses of University of the Basque Country (UPV/EHU) in the 2021/2022 academic year took part in the present study. The characteristics of the selected sample are detailed in Table 1.

In relation to the sample size, this was considered adequate for the validity of the questionnaire and the type of study, as it satisfies the condition of having between five and ten people per item, which suggested a minimum of 300 participants (Roco Videla et al., 2021).

Instrument

The instrument is based on the scale of self-regulation of learning in mathematical problem-solving contexts for university students constructed by Landa et al. (2024). This test consists of 41 items with seven Likert-type response levels, with the values:

Table 1 Sample data in academic years 2021/2022

	Academic year	
	2021/22	
Variables	$n = 402$	%
Gender Identity		
Woman	239	59
Man	148	37
Non-binary	6	1
DK/NO (don´t know/no opinion)	9	2
Baccalaureate mode		
Social Sciences	225	56
Science and Technology	169	42
Arts	3	1
Other	5	1

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.

The previous study by Landa et al. (2024) was carried out with a sample of 269 students of the Primary Education Undergraduate Degree during the 2020–2021 academic year at University of the Basque Country (UPV/EHU). The overall scale, in terms of internal consistency, obtains a value for MacDonald's Omega (ω) of 0.874, a particularly relevant coefficient when working with multidimensional scales (McNeish, 2018). In relation to its factor structure, the KMO values ($0.836 > 0.7$) and the result of Bartlett's test of sphericity ($p < 0.001$) are considered sufficient. The exploratory factor analysis provided a structure composed of seven interrelated factors, but each with their own factorial identity. These factors are described as follows:

> *Factor 1: Students' perception of their ability and how this influences the self-regulation of the resolution process.* This factor not only refers to a self-efficacy that involves students'perception of their abilities, but also explores how they perceive themselves during the problem-solving process, how they engage in challenges and how they evaluate their own performance and progress. An example of this is *item 20: At all times I know what I am doing in a problem, what I am doing it for and how what I am doing serves me in the solution* (seven items, $\omega = 0.792$).
>
> *Factor 2: Ethics.* Dimension proposed by Marbán and Fernández-Gago (2022) and 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. An example of this is *item 4: When I try to understand a problem, even if I have doubts, I don't give up because I take responsibility for solving it* (six items, $\omega = 0.714$)

Factor 3: Problem-solving and personal growth. This factor indicates that students value difficult problems as opportunities for learning and personal growth, showing a positive attitude towards challenges. An example of this is *item 40: I think it is important that a problem is difficult to improve my education and to grow as a person* (six items, $\omega = 0.678$).

Factor 4: Attitude towards the statement. This factor deals with the students'management of their own behaviour, derived from the attitude they adopt towards the statement, i.e., a positive attitude towards the statement leads to proactive behaviour in the problem-solving process. An example of this is *item 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 next time* (eight items, $\omega = 0.742$).

Factor 5: Negative self-efficacy beliefs and external causal attribution. This factor refers to the non-assumption of responsibility in the problem-solving task, attributing the cause of success or failure to external agents, such as luck or help from the teacher. It also refers to the belief in not being able to change ideas or deal flexibly with challenges and, as a result, students may experience a lack of confidence and avoid seeking new strategies or approaches. Examples for this factor are, *item 14: If I have a fixed idea of how to solve the problem, I am not able to change it* and *item 36: The main person responsible for the problem is the teacher* (seven items, $\omega = 0.630$).

Factor 6: Problem-solving method. This factor refers to the method used by the learner to solve the problem, i.e., how the learner acts and what kind of strategies and processes they use to accomplish the task. An example of this is *item 23: I check my tentative conclusions (conjectures) or results to see if they are consistent or if the conditions of the statement are met* (five items, $\omega = 0.710$).

Factor 7: Social Environment. This factor refers to when students ask for help to avoid blockages or overcome difficulties during the activity. An example of this is *item 13 If I don't understand a statement, I am able to ask for help to understand it* (three items, $\omega = 0.659$).

These seven factors explain 61.76% of the total variance and the distribution of the items by factors is as follows:

Procedure

As has already been pointed out in the Introduction, we are interested in establishing relationships between the factors described above to acquire a deeper understanding of learners'self-regulation processes within our context of interest. In particular, we want to identify patterns and to determine which factors have a greater impact on self-regulated learning. For this purpose, Structural Equations Models (SEM) are useful and offer greater flexibility than regression models, which is particularly relevant in our context given the complexity of the process of self-regulation of learning and the presence of multiple variables whose relationships we wish to study, especially in terms of the effects of some factors on others. Moreover, SEM allow us to propose the type and direction of these relationships through a theoretical model that is then contrasted with the information from the observed data. It is precisely the specification of the theoretical model that constitutes the first step in this type of analysis. The design and subsequent interpretation of the structural equation model is carried out by proposing the following model:

Hypotheses in the model (Fig. 1): At the construct-theoretical level, the structural equation model is proposed to be hierarchical. The results obtained in previous studies (Landa et al., 2024) show that one of the seven factors, *Factor 1: Students'perception of their ability and how this influences the self-regulation of the resolution process*, explains a variance of 22%, i.e., it is a factor that can have a significant influence on the self-regulation of students of a Primary Education Undergraduate Degree in problem-solving contexts. In this context, a hypothetical model is proposed where all the factors, except *Factor 5: Negative self-efficacy beliefs and external causal attribution*, are significantly explained by this factor.

The proposed model is then tested using AMOS 28.0 (Arbuckle, 2021) using the maximum likelihood estimation (MMV) method.

The steps followed in this study are listed below: (1) Model specification: Based on the theoretical framework and supported by the results obtained from the exploratory factor analysis. (2) Creation of the structure diagram: The model is tested using AMOS 28.0.0. (3) Verification of the Model: Using a maximum likelihood estimation method. (4) Model evaluation: Calculation of absolute fit indices ($\chi 2$/df; SRMR; RMSEA) and incremental fit indices (NFI; TLI; CFI). (5) Results and Discussion: Analysis and interpretation of results.

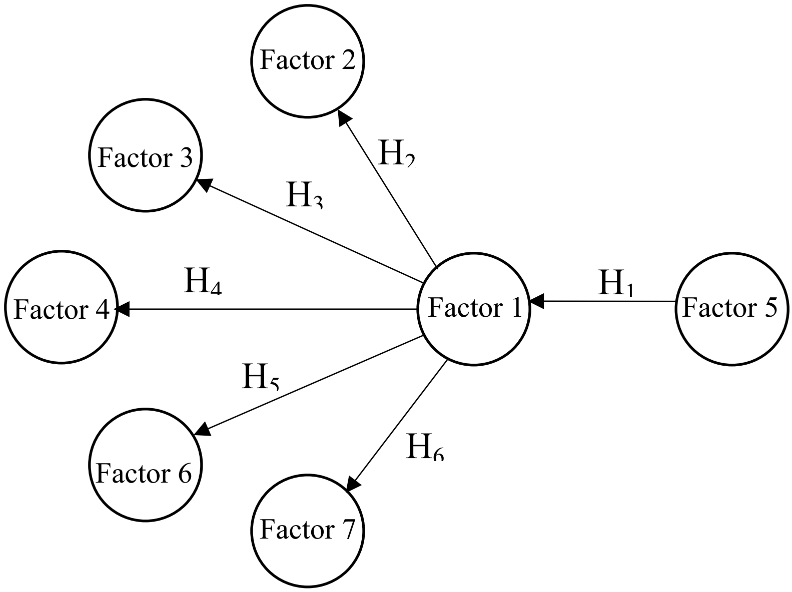

Fig. 1 Hypotheses in the model

Ethics

This project has been approved by the Ethics Committee for research involving human subjects and their data or samples (CEISH-University of the Basque Country (UPV/EHU)) with code M10_2021_087.

Results

Internal reliability

In relation to the reliability of the instrument, in terms of internal consistency, we obtained a value for the MacDonald Omega coefficient of the total scale of 0.873, which supports the reliability of the scale.

Next, taking the theoretical structure and the results obtained from the exploratory factor analysis (Landa et al., 2024) as a reference, the reliability coefficients for each of the seven dimensions are calculated for the new sample (see Table 2).

In fact, if we compare the data from this sample (see Table 2) with the data from the previous academic year (2020/2021) described in the instrument section (see Table 3), the internal consistency coefficients of both are similar. In short, there is sufficient evidence of reliability, both for the individual factors and for the overall scale.

Analysis of the Proposed Model

In this section the proposed hierarchical model is tested. First, the latent structures are confirmed since, as we can see in the table in Appendix 2, where each factor is significant. Therefore, each item is explained by only one of the factors, even though there is a relationship between them. In short, our evidence suggest that the items are measuring the underlying construct to which they are assigned.

Second, in Table 4, the correlations between factors are calculated and as can be seen, Factor 1 loads on four factors significantly, except for Factor 3 which, although it does not reach the level of significance, is very close. Factor 5 is found to load on Factor 1, also significantly.

Table 2 MacDonald's omega values data for the 2021/2022 sample (N = 402)

Factors	MacDonald's Omega
1	0.766
2	0.712
3	0.572
4	0.741
5	0.582
6	0.697
7	0.705

Table 3 Distribution of items by factors

Factors	Items	MacDonald's Omega
Factor 1: Student'perception of their ability and how this influences self-regulation of the resolution process	20, 21, 24, 28, 29, 30, 31	0.792
Factor 2: Ethics	1, 2, 3, 4, 12, 22	0.714
Factor 3: Problem solving and personal growth	33, 37, 38, 39, 40	0.678
Factor 4: Attitude to the statement	5, 6, 7, 8, 9, 10, 11, 15	0.742
Factor 5: Negative self-efficacy beliefs and external causal attribution	14, 16, 25, 32, 35, 36, 41	0.630
Factor 6: Problem-solving method	17, 18, 19, 23, 27	0.710
Factor 7: Social Environment	13, 26, 34	0.659

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

Table 4 Parameter estimation estimates of standardized regression weights

	Estimated value	Standard error of regression weight	*C.R*	*p-value*
F1 ← F5	−0.330	0.089	−3.728	< 0.001
F6 ← F1	1.026	0.119	8.632	< 0.001
F2 ← F1	0.833	0.105	7.907	< 0.001
F3 ← F1	0.267	0.137	1.939	0.052
F4 ← F1	0.888	0.121	7.364	< 0.001
F7 ← F1	1.000	0.104	3.375	< 0.001

Estimated value, standard error of regression weight, critical coefficient for regression weight, significance level of regression weight from left to right, respectively

In order to examine to what extent the model accurately represents our theoretical framework and how well it helps to understand the relationships between the variables under consideration we proceed now to assess the goodness of fit of the model by a combination of the different fit indices as recommended by the scientific literature: χ^2 divided by the degrees of freedom (χ^2/dl), RMSEA (Root Mean Squared Error of Approximation), which refers to the amount of variance not explained by the model per degree of freedom, SRMR (Standardized Root Mean Square Residual), NFI (Normed Fit Index, Bentler & Bonett, 1980), TLI (Tucker-Lewis coefficient, also known as Bentler-Bonett Non-Normed Fit Index) and CFI (Comparative Fit Index; Bentler, 1990), a coefficient that compares the χ^2 of two models, an independent model that maintains that there is no relationship between the variables in the model and the model proposed by the researcher. About the coefficient of χ^2/dl, a value of 4 is considered to reflect an acceptable fit, while those values close to 2 are very good. RMSEA values should be less than 0.08 to have an acceptable fit, or close to 0.05 to obtain a good fit. The NFI, TLI and CFI values should exceed 0.90 (Batista-Foguet et al., 2004). In the case of our model, the following values for each index were obtained: Chi-square (χ^2) = 1633.83, df = 769 and χ^2/df = 2.12, which indicates a good fit of the model to the data. In turn, we obtain that NFI = 0.659, TLI = 0.768 and CFI = 0.782. The standardised root mean square is SRMR = 0.066 and the RMSEA = 0.053 < 0.08, which translates into an adequate fit (Hu & Bentler, 1999). As can be seen, some values seem to support the idea of the model fitting the observed data (SRMR, RMSEA; χ^2/df) while others do not, most notably the NFI, the value of which is far from ideal. Under these circumstances the decision to accept or reject the model must incorporate other factors than just fit indices such as the theoretical rationale of the model itself, its complexity and even the context for data collection together with eventual practical implications of the results. Considering all these factors altogether we decided not to reject the model but accepting that further actions are required to improve it as will be pointed out later when discussing limitations and future research.

Figure 2 shows the factor structure of the proposed model, as well as the correlations of the items with their factors and the weights of Factor 5 on Factor 1 and of Factor 1 on the rest of the factors.

The diagram of this model allows us to analyse the relationships between the dimensions. First, it should be noted that *Factor1: Students' perception of their ability and how this influences self-regulation of the problem-solving process*, has a high level of explanation over the rest of the factors.

From the perspective of the proposed model, Factor 1 significantly influences all factors, except Factor 5 and it has the greatest effect (0.92) on *Factor 6: Problem-solving method*. These variables have a direct relationship, i.e., in the context of problem solving, as the perception of self-efficacy increases, students are more likely to apply effective strategies to solve problems and to evaluate them, justifying their choice, analysing errors and seeking improvements.

Ethics is the second variable on which the main factor has the greatest impact (0.85). These two factors have a direct relationship with each other, i.e., students with a high perception of self-efficacy in the mathematical problem-solving task have a higher level of commitment, perseverance and patience when approaching the task.

On the other hand, Factor 1 also has a relevant effect on *Factor 3: Problem solving and personal growth* and on *Factor 4: Attitude towards the statement* (0.78 and 0.71, respectively). The result, in relation to Factor 3, indicates that students who have a high perception of self-efficacy in the mathematical problem-solving task see challenges as opportunities for growth and development, which fosters their intrinsic motivation and willingness to try and show greater interest in the task, because they believe it is beneficial for their personal or professional goals. And, in relation to Factor 4, it suggests that, as self-efficacy increases, students'attitudes towards a problem statement improve, which may lead to more effective and successful behaviour in solving mathematical problems.

Similarly, Factor 1 also has a direct effect (0.57) on *Factor* 7: *Social environment*. The relationship between the variables is direct, i.e., if students are confident in their ability to learn and believe in their competence, they will be more willing to ask for

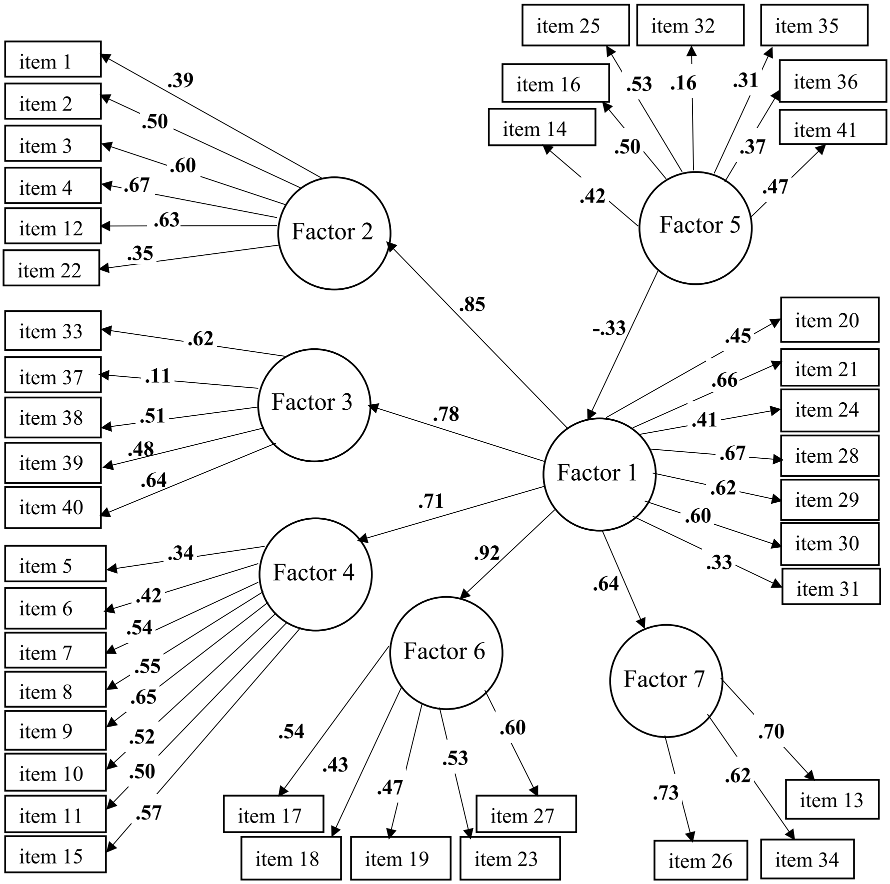

Fig. 2 Final model

support and seek additional resources to overcome the challenges they may encounter in solving mathematical problems.

The reading of these results infers that *Factor 1: Students'perception of their ability and how this influences the self-regulation of the solving process* acts as a moderating variable in the level of self-regulation of primary school initial trainers in mathematical problem-solving contexts. That is to say, the level of self-regulation differs in a clear way, depending on the students' perception of their degree of self-efficacy when facing a mathematical problem.

Finally, Factor 5 exhibits a negative effect over Factor 1 in the model (−0.33), with the former characterized as *Negative self-efficacy beliefs and external causal attribution.* Factor 5 has all its items formulated in the negative and the relationship between these two variables is indirect, i.e., to the extent that students attribute failures or successes to external causes such as the difficulty of the task, luck, the teacher, etc., the students'self-efficacy beliefs decrease and this, in turn, influences their commitment and initiative in solving mathematical problems. The decrease in self-efficacy beliefs in turn influences commitment and initiative-taking in solving mathematical problems. It is important to point out that in this dimension, affective aspects such as stress, frustration and fear or the inability to manage emotions (*item 41: If the problem is difficult, I am not able to generate positive emotions to solve it*). This result indicates that students with a high level of stress will have less confidence in their ability to solve mathematical problems.

Discussion and Conclusions

The present study tests the dimensionality of a questionnaire on self-regulation in mathematical problem-solving contexts for university students and the results obtained show that it has a fairly good level of construct validity, as well as an acceptable overall and dimensional reliability. The results, in turn, largely confirm the item classification established in the theoretical framework, i.e., the identified factors are coherently related to key aspects of self-regulated learning in the context of mathematical problem solving, supporting the latent structure identified by the exploratory factor analysis of Landa et al. (2024). Furthermore, through a proposal based on a structural equation model we have been able to examine the interactions between these factors and thereby gain a better understanding of the underlying mechanisms and relationships between them. In this way, valuable information has been obtained to help understanding the cognitive, affective and social processes involved in the mathematical problem-solving process. This hierarchical model proposed shows Factor 1 as a predictor or influencing factor on the other factors, with Factor 5 being the only exception. This is interesting as it tells us that the more students rely on their own abilities and the greater sense of self-control they have while solving a mathematical problem the better their attitudes, their behaviours, their ethical views, their critical thinking and their management of resources are. In fact, results show that the influence of self-efficacy beliefs on the method or the strategies used by students to solve mathematical problems is not only strong but is, in fact, a significant one. This result is supported by research indicating that self-efficacy affects the quality with which students process information as well as select and use learning strategies in mathematical tasks and in mathematical problem solving (Martínez Vicente & Valiente Barroso, 2019; Throndsen, 2011). On the other hand, Factor 1 also plays an important role in Ethics (Marbán & Fernández-Gago, 2022), i.e., students who have high self-efficacy in their ability to solve problems tend to set challenging goals, seek solutions autonomously and show greater perseverance in the search for answers. This result adds evidence to those obtained in other studies (Martínez Vicente & Valiente Barroso, 2019; Usher & Pajares, 2008).

More specifically, the results show how self-efficacy has a significant impact on Factor 3: Problem solving and personal growth, a factor that is related to motivation, a dimension that appears in Zimermman's model (Zimmerman, 2002). In this vein we find that several studies indicate that motivational beliefs are influenced by aspects such as self-efficacy, interest and goals, aspects closely related to performance in mathematics in general (Liu et al., 2024; Perry, 2011) and in problem solving in particular (Efklides, 2011; Tzohar-Rozen & Kramarski, 2017), and the results obtained in this study provide further evidence in this regard.

Similarly, the impact of Factor 1 is also significant in students'management of their own behaviour, a dimension in Zimermman's model (Zimmerman, 2002). A positive attitude to the problem statement, driven by a belief in one's own ability to address and solve mathematical problems, can lead to proactive and committed behaviour in the search for solutions. This result confirms those achieved in previous studies in which students with greater self-confidence are less anxious and generally have better attitudes towards mathematics, both at secondary school (Palacios et al., 2013) and at university level (Pérez-Tyteca et al., 2008).

Again, we find that self-efficacy influences another of the characteristic dimensions of self-regulated learning in Zimermman's model (Zimmerman, 2002), that named Social Environment. A person with high self-efficacy seeks or asks for help in the face of challenges; this result reinforces those collected by Panadero and Alonso-Tapia (2014) in which students with low performance are reluctant to ask for help because they do not know what, when and how to ask, nor whom to ask and, in addition, they are afraid of not appearing competent.

Concerning Factor 5: Negative self-efficacy beliefs and external causal attribution, which has all its items formulated in a negative direction, albeit in a moderate way, influences Factor 1: Students'perception of their ability and how this influences the self-regulation of the mathematical problem-solving process, i.e., as the level of stress, frustration and fear increases, the student's perception of their ability decreases. It is worth mentioning at this point that although beliefs have been frequently placed at the core of teaching practices (Climent et al., 2024; Schoen & LaVenia, 2019), this result adds evidence to that provided by other researchers who claim that pre-service teachers with high levels of anxiety towards mathematics have a low perception of self-efficacy and that they tend to avoid contact with this subject (Gómezescobar & Fernández, 2018; Marbán et al., 2021).

To summarize, the results of this research suggest that perceived self-efficacy is not only related to self-regulation and problem solving independently, but that it also modulates the influence of self-regulation on mathematical problem solving. This approach highlights the importance of Factor 1, i.e., the students'perception of their ability, which is not attributable to cause and effect, but which is particularly determinant for self-regulation outcomes and thus for mathematical problem-solving performance. Therefore, educational interventions focussing on the items underpinning this factor can, in the context of mathematical problem solving, constitute a valuable strategy to promote better self-regulation of learning in students taking a Primary Education Undergraduate Degree. In this regard, the Morán-Soto and Benson (2024) study points out that identifying university students' levels of mathematics self-efficacy can help educators better understand their students when they perform mathematic activities and develop learning environments that leverage their confidence in these tasks. The regulatory role of mathematics self-efficacy in the specific context of future teachers'development was also examined by Jenßen et al. (2022), who highlighted that enhancing mathematics self-efficacy can play a key role in strengthening future teachers'resilience to feelings of shame. In fact, experimental research has demonstrated that certain instructional and social processes significantly influence self-efficacy and achievement, including such processes exposure to social models, setting proximal and specific goals, receiving social comparative information indicating favourable performance, verbalizing thoughts aloud while learning, and self-evaluating one's capabilities (Hidayatullah et al., 2024; Schunk & Usher, 2019). Within this framework, pre-service teachers'beliefs regarding mathematics are important because they will influence the way they will teach mathematics. From this perspective, Hannula et al. (2005) propose activities which enable pre-service teachers to reflect on their own experiences of learning and teaching mathematics. For example, to explore content with specific materials or to collaborate and enter into discussion with their peers. All these lead to the proposal to design training activities that prioritize discussion and reflection, including the affective dimension, and in which mistakes would be accepted as opportunities to stimulate reflection and foster learning (Liljedahl et al., 2007; Panero et al., 2023).

Limitations and Directions for Future Research

As noted above, the model fit analysis carried out in this study shows that some indicators have not reached their optimal value -in some cases not even an acceptable one- and, therefore, do not provide evidence for us to fully accept the model, although the good values of some relevant indices together with the soundness of the theoretical framework that defines the model and the consideration of its complexity prevent us from rejecting it. Thus, further actions must be taken to improve the model and reassess it in order to finally decide on its acceptance or rejection: further replication with a larger sample should be carried out to analyse more thoroughly the robustness of the model, removing or combining those variables or paths that have contributed the least to the overall theoretical framework.

In addition, the structural equation model used in this study should not be considered as the only possible option. It would be useful to consider other hypothetical possibilities, such as mutual dependence and reciprocity between factors, which were not explored in the present work. Exploring new correlations and even the incorporation of new variables in future research may enrich our understanding of university students'self-regulation in the context of mathematical problem solving.

In any case, from the evidence provided in this study, very useful information can be extracted with which to design a teaching experiment based on profiles identified in the classroom where the main variable is the perception of self-efficacy and cooperative learning in mathematical problem solving (see Appendix 3). In short, as a future line of research, it is proposed to design interventions and teaching strategies that foster the development of self-regulation and endeavour to improve academic performance in mathematics and in mathematical problem solving in the context of teacher education.

Appendix 1

Table 5

Table 5 Questionnaire on self-regulation of learning in problem-solving contexts

No	Statement
1	I stop reading a problem as soon as the problem statement is more than 5 lines long
2	If the statement is difficult to understand, I read it several times and try to understand it
3	Even if a problem statement makes me unsure, I try to solve the problem
4	When I try to understand a problem, even if I have doubts, I don't give up because I take responsibility for solving it
5	After reading a problem statement I highlight or represent the essential conditions or information of the problem
6	If I don't understand the statement I talk to myself to try to understand it
7	If I feel insecure when I read a statement, I have resources to help me feel more confident
8	As I'm reading, I encourage myself by reminding myself that understanding the statement depends on what I try and how I try
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 next time
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,…
11	If I have understood the statement of a problem, I look at what worked for me so as to be able to repeat it or improve on it in the next problem
12	I tend to keep in the habit of taking time to understand the issues
13	If I don't understand a statement I am able to ask for help to understand it
14	If I have a fixed idea of how to solve the problem I am not able to change it
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.)
16	After a while of weighing up plans, I'm not usually clear about which one I'm going to choose
17	Before writing a tentative conclusion about the solution (conjecture) I think about whether it makes sense
18	I am able to express my tentative conclusions about the solution (guesses), even if I don't know if they are right
19	I am able to express my tentative conclusions about the solution (conjectures) even though I am embarrassed to express them
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
21	If, after overcoming a difficulty, another difficulty arises in the problem, I look for ways to overcome it myself
22	I persist in pursuing my plan or idea, even if I am not sure if it is right
23	I check my tentative conclusions (conjectures) or results to see if they are consistent or if the conditions of the statement are met
24	I am able to control my emotions while solving a problem
25	If, when I check a solution, I realise that it is wrong, I am not able to take advantage of what is right to look for another way

Table 5 (continued)

No	Statement
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
27	I am able to be critical of myself, questioning the steps of my solution
28	I am able to sequence, describe and correct the steps taken to reach the solution
29	I am able to see the possibilities of my solution to extend it to other problems
30	I am able to take an interest in other solutions and see the advantages or disadvantages with my own
31	I prefer challenging tasks (therefore a bit more difficult and adventurous) to exercises where I know what I have to do
32	I don't engage in challenges that provoke fear, stress, frustration or any negative emotions in me
33	I find it important when solving problems to do them myself
34	If I don't know how to do it myself, I find it important to learn from my peers
35	I am not primarily responsible for the resolution of the problem
36	The main person responsible for the problem is the teacher
37	I am capable of thinking, even for a week, about a problem that has not come up
38	When I solve problems I am so focused that it is as if time stands still
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
40	I think it is important that a problem is difficult in order to improve my education and to grow as a person
41	If the problem is difficult, I am not able to generate positive emotions for its resolution

Appendix 2

Table 6 Parameter estimation

	Estimated value	Standard error of regression weight	*C.R*	*p-value*
Item11 ← F4	1			
Item9 ← F4	1.373	0.162	8.474	< 0.001
Item8 ← F4	1.295	0.169	7.677	< 0.001
Item7 ← F4	1.095	0.147	7.45	< 0.001
Item6 ← F4	0.856	0.133	6.444	< 0.001
Item17 ← F6	1			
I16REC ← F5	0.976	0.172	5.673	< 0.001
I14REC ← F5	0.814	0.155	5.268	< 0.001
Item20 ← F1	1			
I25REC ← F5	1			
Item28 ← F1	1.082	0.109	9.944	< 0.001
Item30 ← F1	1.059	0.112	9.465	< 0.001
Item31 ← F1	0.834	0.128	6.507	< 0.001
I35REC ← F5	0.929	0.209	4.452	< 0.001
I36REC ← F5	0.902	0.191	4.727	< 0.001
I41REC ← F5	0.943	0.171	5.529	< 0.001
Item33 ← F3	1			
Item24 ← F1	0.893	0.117	7.613	< 0.001
Item10 ← F4	1.264	0.169	7.486	< 0.001
Item15 ← F4	1.013	0.133	7.625	< 0.001
Item27 ← F6	0.942	0.107	8.815	< 0.001
Item23 ← F6	0.893	0.088	10.157	< 0.001
Item19 ← F6	0.947	0.113	8.374	< 0.001
Item18 ← F6	0.729	0.095	7.678	< 0.001
Item13 ← F7	1			
Item26 ← F7	1.038	0.099	10.495	< 0.001
Item34 ← F7	0.834	0.1	8.307	< 0.001
Item29 ← F1	1.008	0.103	9.818	< 0.001
Item21 ← F1	0.977	0.099	9.886	< 0.001
Item4 ← F2	1.529	0.171	8.952	< 0.001
Item3 ← F2	1.326	0.152	8.713	< 0.001
Item2 ← F2	1			
Item40 ← F3	1.237	0.143	8.655	< 0.001
Item39 ← F3	1.041	0.148	7.048	< 0.001
Item38 ← F3	1.226	0.163	7.525	< 0.001
I1REC ← F2	0.874	0.139	6.311	< 0.001
Item22 ← F2	0.646	0.12	5.382	< 0.001
Item37 ← F3	0.363	0.163	2.228	0.026
I32REC ← F5	0.335	0.153	2.191	0.028
Item5 ← F4	0.681	0.128	5.329	< 0.001
Item12 ← F2	1.41	0.164	8.591	< 0.001

Estimated value, standard error of regression weight, critical coefficient for regression weight (CR), significance level of regression weight

Appendix 3

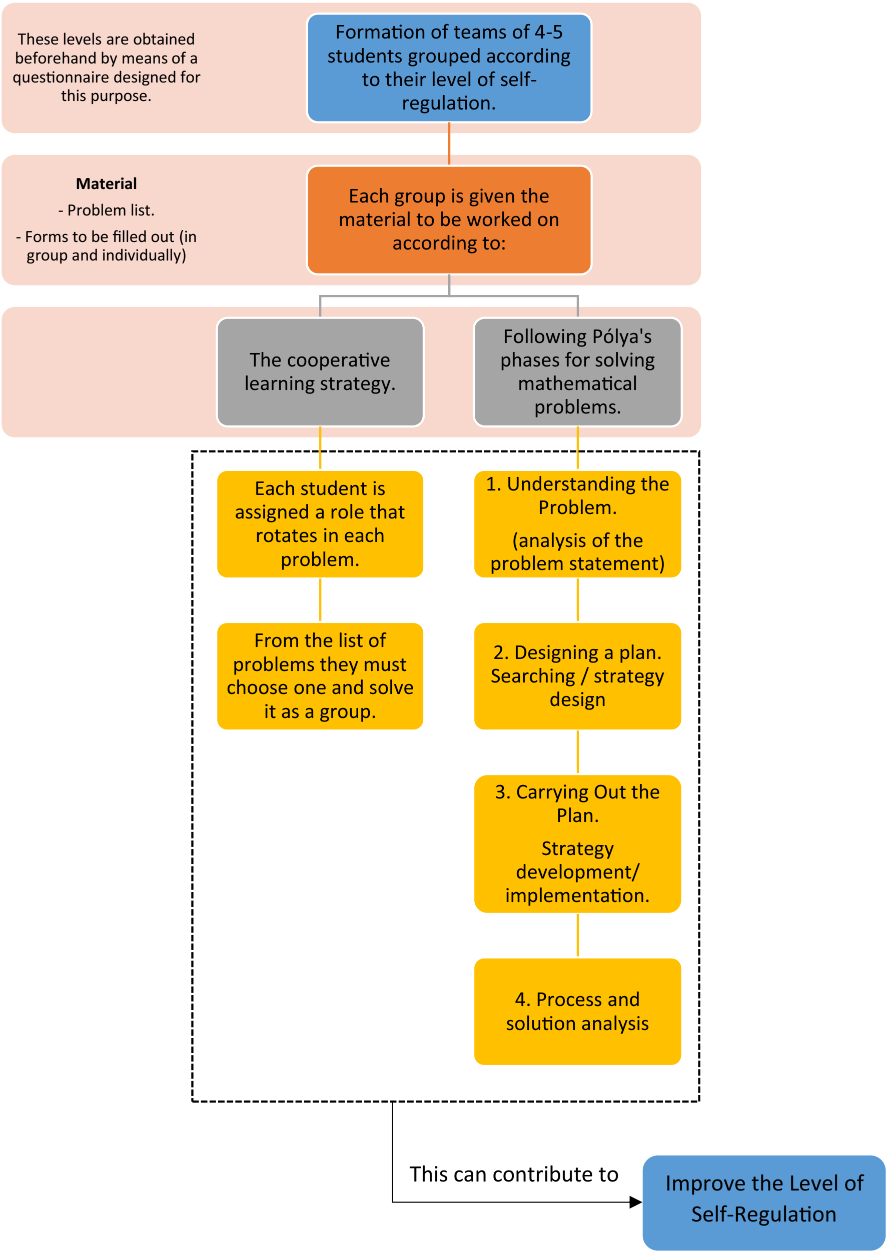

Fig. 3 Diagram of the implementation

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