

Article

Can Mathematics Achievement Be Predicted? The Role of Cognitive–Behavioral–Emotional Variables

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Abstract: The current society is based on science and technology, depending partly on mathematics. It leads to citizens' success in school mathematics, being measured through achievement, which can be predicted by affective, cognitive, and behavioral variables. The aim of this study was to determine the extent to which self-concept, learning strategies, attitude towards science and mathematics, school environment, and previous scores in science and mathematics predict achievement in mathematics. A convenience sample of 352 pupils taking part in a science, technology, engineering, and mathematics (STEM) experimentation outreach program belonging to state schools and state-funded schools from rural and urban environments was analysed. The instrument was composed of the Auzmendi scale of attitude towards mathematics modified, the attitude towards school science, the AUDIM questionnaire for self-concept (physical, social, personal, academic, and general), and the CEA questionnaire for learning strategies (emotional control, critical and creative thinking, and metacognition). Sex, type of school, and school environment were covariates. A binary logistic regression model was obtained for mathematics achievement, which correctly classified 82.1% of students, with previous science and mathematics achievement, science achievement, and critical and creative thinking as predictors, and urban schools playing a positive role. Implications of these predictors on mathematics education are discussed.

Keywords: mathematics; achievement; attitude; creative thinking; self-concept; learning strategies



Citation: Fernández-Cézar, R.; Solano-Pinto, N.; Garrido, D. Can Mathematics Achievement Be Predicted? The Role of Cognitive–Behavioral–Emotional Variables. *Mathematics* **2021**, *9*, 1591. <https://doi.org/10.3390/math9141591>

Academic Editor: José María Marbán

Received: 8 June 2021

Accepted: 3 July 2021

Published: 7 July 2021

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1. Introduction

Mathematics is a key science for personal fulfilment and participation in school, society, and the labour market in the 21st century [1]. It also appears to be a critical academic filter for students' educational pathways [2]. Mathematics is an important field in 21st century society, which is highly reliant on technology. All science depends on mathematics, so its management is crucial for citizens in modern society. It is a focus of teachers, students, and families, who mainly measure how students comprehend mathematics through achievement scores.

Although there are several definitions for achievement, focusing on the behavioral perspective, and more on the process from the cognitive one [3], it has typically been measured from Western-dominant insights [4], independent of demographics and culture. However, more recent studies have indicated differences in mathematics achievement among children of different cultural backgrounds [5], ethnicities [4], and sexes [6]. The results have suggested that certain background and noncognitive factors are critical in influencing students' mathematics achievement. Several of these factors, such as sex or school environment, have been weakly analysed. Nonetheless, some cognitive factors have been deeply analysed in terms of their individual relation to mathematics achievement. Such is the case for attitudes towards mathematics and science [7], self-concept [2,8,9], and learning strategies in connection with achievement [4,10]. Among these sociocultural,

cognitive, and behavioral factors, only in a few papers are they analysed in a combined manner regarding effects on achievement. Such is the case for Pitsia et al.'s [11] work with Greek students, who performed a multilevel analysis with PISA (Programme for International Student Assessment) data, or the work of Hann [12], who obtained conclusions on the influence of demographics and noncognitive factors with USA PISA data. In both cases, conclusions were drawn for 15-year-old students, while there are no studies on the effect of noncognitive variables and mathematics achievement for younger students. Therefore, this paper aims to determine whether and to what extent self-concept, attitude towards science and mathematics, learning strategies, and previous achievement scores predict mathematics achievement in young children, with sex and school environment as covariates.

The covariates were chosen because of the lack of clarity on their influence on achievement. Cross-national studies on the effect of sex on mathematics achievement did not find any effect of sex, but did find an effect of culture. However, it seems that the sex gap is smaller for egalitarian and large societies [13–15]. On the other hand, there is a lack of literature on the effect of rural dwelling on achievement.

Affect and Mathematics

The study of attitude towards mathematics education is fundamental given its recognized influence on student performance in this area and on subsequent course choices in STEM, the acronym for science, technology, engineering, and mathematics [16]. McLeod [17] considered attitude to be a component of the affective domain, together with emotions and beliefs. De Bellis and Goldin [18] also considered it a component of their model along with beliefs, emotions, and values. Despite agreeing that emotions are feelings towards an object and can thus be positive or negative, Phillip [19] considered that, unlike emotions, attitudes are more durable. Han and Carpenter [20] assumed attitudes to be affective, cognitive, and behavioral reactions to an environment or object, and in the field of mathematics education, the object is mathematics. This conceptualization of attitude composed by cognitive, affective, and behavioral components is aligned with Gómez Chacón [21], who defined attitude as an evaluative behavioral predisposition that is reflected in personal intentions and influences behavior. This is the framework in which this work is settled.

Attitude towards mathematics involves beliefs about the effectiveness of mathematics education and the interest students have in performing mathematical tasks in academic and everyday situations [22]. For Goldin [23], attitude is a stable predisposition to feel in situations involving both cognition and affect. The attitude towards mathematics becomes a tool describing the interactions between cognitive and affective aspects of mathematical tasks [24]. Attitude is built on past experiences with mathematics and can be seen as generating a positive or negative disposition towards mathematics [25]. Several studies have shown the relationship between positive attitudes and academic performance in mathematics [26,27] and negative attitudes and educational achievement in students at various educational stages [28,29]. Therefore, attitude towards mathematics is an individual state that predisposes individuals to mathematical behavior and includes cognitive, behavioral, and affective components. The cognitive component is what the individual believes or thinks about mathematics; the affective component is his/her feeling towards mathematics; and the behavioral component is the tendency to respond to mathematical learning in a given manner, e.g., through the implementation of learning strategies [20]. The components are interrelated and contribute to mathematics achievement to some extent and to the learning of mathematics. Besides, several studies have found that mathematics anxiety towards tests and exams predicts achievement [30], with anxiety being considered by some authors [31,32] as the component of attitude that is the most strongly related to achievement [33].

Self-concept forms part of the affective component of attitude. Self-concept is influenced by feedback received from others and individuals' evaluations of their performances [34]. In the work of Marsh [35], the author cited several studies that showed

academic achievement to be related to academic self-concept, but not to non-academic components in elementary and middle-school students [36]. A positive self-concept is frequently posited as a variable that facilitates certain desired outcomes, such as academic achievement [34,37,38]. In addition, several authors [8,39] have argued that prior self-concepts influence subsequent achievements and that prior achievements affect subsequent self-concepts. These loop relations also apply to the field of mathematics, where a positive relationship between students' mathematics achievement and math self-concept is found at various ages. In this regard, Lee and Kung [8] found this influence of self-concept and math achievement in Taiwanese seventh graders (approximately 15 years old), and Bofah [39] found it in African students of nine different countries at approximately 15 years of age. Niepel et al. [9] found positive relationships between self-concept and math achievement mediated by academic approach goals in German students between 8.58 and 15.68 years of age. In addition, the general consensus is that boys exhibit significantly higher math self-concept than girls, although girls exhibit higher mathematics achievement than boys [8].

In the learning process, part of the student behavior is implicit in learning strategies. Learning strategies (LSs) are related to the behavioral component of attitude, considering LSs as the way in which a student approaches a subject, and are usually related to previous experiences and match the student's belief about the subject (i.e., mathematics). They are also linked to the skills to be developed and involved in the learning process such as reading comprehension [40]. Some studies consider two main LS categories: deep strategies, which involve relating to previous knowledge and exploring the patterns among sources of information; and surface strategies, which involve repeated rehearsals and memorization [10]. The first category is linked to higher-order thinking skills (HOTS) and the second is linked to lower-order thinking skills (LOTS), according to the original and revised Bloom taxonomy [41]. Nonetheless, there is no clear relation between deep or surface strategies and achievement because the relation is mediated by cultural factors [4]. In addition, attitude is not contemplated as an LS in this taxonomy. A more complete taxonomy is provided by Beltrán [42], who considers not only knowledge, but also affect inherent aspects of the learning process, so attitude and emotions need to be considered as LSs.

From constructivist insight into the learning process, LSs are considered the building blocks of knowledge of the world around us, which interact with cultural factors [4]. In this regard, the differences among processes, strategies, and techniques established by Beltrán [42] are remarkable. Regarding the first ones, processes, the author considered them as present in the teaching–learning of any content, intended to be generalizable. To reach the abovementioned generalization, the subject uses LSs that include behavioral and visual techniques. In this framework, strategies and techniques were taken into account to create the CEA questionnaire of LSs [43]. Regarding LSs, other authors have considered them to be flexible and adaptable to various situations [44], which is seen a positive aspect for the development of mathematical skills [45] through the combination of discovery and experimentation to promote the creation of abstract mathematical objects [46].

In the CEA questionnaire, not only emotional and metacognitive aspects are considered, but also critical and creative thinking, needed to develop mathematical skills [43]. Critical and creative thinking are considered part of HOTS [41] and are needed to deal with information and offer new solutions to new problems, skills related to mathematics learning [47,48]. Moreover, Liu et al. [49] proved that higher achieving students used them to a greater extent than lower achieving students.

Both individual issues and school-related factors influence mathematics achievement. Thus, Aru and Kale [50] investigated the effect of school-related factors and early learning experiences on mathematics achievement in primary school students. The authors performed a multilevel analysis and found that the skills acquired during the early years had statistically significant effects on the mathematics achievement scores of primary school students. At the school level, they highlighted the importance that the school attaches to mathematics achievement. Additionally, Acelajado [51] analysed the mathematics ex-

periences of 60 college students enrolled in math courses and found that mathematics was considered important, but quite challenging. Moreover, students' achievement was affected by their attitudes towards mathematics and mediated by their understanding of the lessons.

Taking into account the reviewed literature, there is evidence of individual relationships between mathematics achievement on the one hand and self-concept, LSs, and attitudes on the other hand. However, there are no studies where all these variables were analysed together to determine which are stronger predictors of mathematics achievement. Therefore, this paper aims to develop a model for mathematics achievement in terms of attitude towards mathematics, self-concept, LSs, and past mathematics and science achievement as its predictors, with sex, type of school [52,53], and rurality as covariates.

2. Materials and Methods

2.1. Participants

The sample comprised 352 pupils of schools who applied for participation in the STEM experimentation outreach program "To know the science of today opens the doors of tomorrow" in the 2017–2018 academic year. The outreach programme consisted of a short intervention using scientific experiments and was described in Fernández-Cézar et al. [54]. Seven schools from Castilla La Mancha, Spain, participated. The majority ($n = 5$) were state schools (SSs) and the others were state-funded schools (SFSs), named also by Arellano and Zamorro [52]. The students were 5th and 6th primary education (PE) graders, aged between 9 and 12 years old (10.50 ± 1.11) and taking mathematics and science, which are the STEM courses in the Spanish curriculum. Taking into consideration sex, school environment (rural or urban), and school type (SS or SFS), the sample included 172 boys, 184 children from rural schools, and 239 children from SSs.

2.2. Instruments

In this study, the instruments that were part of the questionnaire were chosen according to the following criteria: originally written in Spanish to avoid translation and not lengthy to avoid possible fatigue among young students. Thus, authors have measured the attitude towards mathematics with the Auzmendi scale of attitude towards mathematics modified, ASMAM [54]. The items were evaluated on a five-point Likert scale, where 1 means totally disagree and 5 means totally agree. As the items composing this factor refer to anxiety, smaller scores show a better attitude towards mathematics, with values ranging from 10 to 50. The internal consistency measured through Cronbach α was 0.743.

The attitude towards science was measured with the attitude towards school science scale, ASSci [54]. In this case, higher scores indicate a more positive attitude towards school science, with scores ranging from 8 to 40. The items were evaluated on a five-point Likert scale, where 1 means totally disagree and 5 means totally agree, providing an internal consistency, as measured by Cronbach's alpha coefficient, of 0.804.

Self-concept was measured through the AUDIM questionnaire, whose psychometric properties have been reported in Rodríguez and Fernández [22] and Jiménez et al. [55]. For this study sample, the internal consistency was measured by Cronbach's alpha coefficient, yielding a value of 0.741, more than acceptable for social sciences. Rodríguez and Fernández proposed a factor structure of the instrument that has been adopted in the present study. The factors are academic self-concept, social self-concept, physical self-concept, personal self-concept, and general self-concept. Each item was evaluated on a five-point Likert scale from 1, meaning false, to 5, meaning true.

LSs were measured with the *Estrategias de aprendizaje* CEA questionnaire, by Beltrán et al. [43], who reported its psychometric properties for children between 12 and 16 years of age. In the original questionnaire, four factors were identified: awareness scale (motivation, attitude, and emotional control subscales), elaboration scale (elaboration, organization, and selection subscales), personalization scale (transfer, critical and creative thinking, and recovery subscales), and metacognition scale (planning/evaluation

and regulation subscales). In this study, the following subscales were utilized: emotional control, critical and creative thinking, planning/evaluation, and regulation. The items were assessed on a five-point Likert scale from 1 (never) to 5 (always). The Cronbach alpha for internal consistency was 0.626, acceptable for social sciences.

Demographics and achievement levels (average test scores [4]) were self-reported by the participants supported by their teachers, taking into account that passing grades in the Spanish educational system correspond to scores of 5 or above [56] on a scale of 10.

2.3. Procedure

Schools applied through the www.nanomadrid.net (accessed on 8 June 2021) program website for participation in the study. The questionnaires were delivered to the schools to be administered. A number code was assigned to each class, and the alphabetical order of students on the class roster was used to order the students and to guarantee anonymity of respondents. The applicant teachers or school principals returned all the questionnaires to the researchers. They were informed about the assessment protocol administration and voluntary participation. All students and families gave their informed consent for inclusion before they participated in the study and knew that they were free to leave the program at any time. The study was conducted in compliance with the Helsinki Declaration.

2.4. Data Analysis

First, we collected descriptive and correlational statistics. Then, to explore and determine the unique influence of each factor (i.e., attitude towards mathematics, attitude towards school science, self-concept, and LSs) on achievement in mathematics, we also conducted a binary logistic regression analysis in SPSS (Windows version 24), provided that none of the considered predictors followed a normal distribution (e.g., attitude towards mathematics, attitude towards school science, self-concept, and LSs; K–S test, $p < 0.05$). For that purpose, mathematics achievement (K–S test, $p > 0.05$) was transformed into a categorical variable, assigning the no passing grades to the fail category, that is, grades under 5 points, and the passing grades to the pass category, that is, scores of 5 points or above. Non-parametric inferential tests are used for analysis of the mean differences, and the eta-squared coefficient, η^2 , for the effect size or the intensity of the differences. Values of eta-squared lower than 0.1 mean a small difference, between 0.1 and 0.3 mean a moderate one, and above 0.5 mean a high difference [57]; rurality and type of school were included as covariates. Thus, the results are presented by taking into account the categorical variable created for mathematics achievement as the dependent variable.

3. Results

The descriptive statistics for the studied variables, including demographics, according to mathematics achievement (i.e., fail vs. pass) are presented in Table 1.

Regarding our variables of interest, analyses showed that there were no differences between groups in several components of self-concept (i.e., social, physical, personal, and general) and LS (i.e., metacognition: planning and evaluating, and regulation) (all with $p > 0.05$). However, the results show differences between groups in academic self-concept ($F = 19.036$, $p < 0.001$, $\eta^2 = 0.06$), in emotional control ($F = 15.184$, $p < 0.001$, $\eta^2 = 0.05$), and in critical and creative thinking ($F = 12.176$, $p < 0.005$, $\eta^2 = 0.04$) LS, with all of them showing small effect sizes.

The correlations among the variables were used to determine whether to include them in the model. The Spearman correlation coefficients are shown in Table 2. The results show significant positive and strong relationships between mathematics achievement and science achievement, previous mathematics achievement, and previous science achievement, provided that the $R_{\text{Spearman}} > 0.5$, while it is negative and moderate for mathematics achievement and attitude towards mathematics. The relationship between mathematics achievement and the attitude towards science is much weaker than with the previous attitude, although it is even with statistical significance.

Table 1. Demographics and study variables of participants.

	Mathematics Achievement	
	Fail	Pass
N	159	193
Age (years)	10.80 (1.08)	10.53 (1.09)
Sex (M/F)	78:81	94:99
School environment (R/U)	85:74	99:94
School type (SFS/SS)	55:104	58:135
Science achievement	6.70 (1.60)	8.07 (1.44)
Attitudes		
Towards Mathematics	24.73 (7.10)	19.92 (6.41)
Towards Science	37.31 (80.07)	36.25 (72.98)
Self-concept		
Academic	30.51 (4.51)	32.56 (4.11)
Social	30.77 (4.36)	31.52 (3.89)
Physical	31.22 (4.94)	31.74 (4.62)
Personal	23.54 (3.15)	23.68 (3.09)
General	16.94 (2.63)	18.91 (2.35)
Learning strategies		
Emotional control	17.10 (4.27)	18.71 (4.19)
Critical and creative thinking	40.52 (6.24)	43.50 (5.75)
Metacognition: Planning and evaluating	25.72 (5.22)	25.52 (4.65)
Metacognition: Regulation	12.30 (3.63)	12.34 (3.51)

Regarding self-concept, there is a positive and moderate relation of mathematics achievement with academic self-concept, and a weak relation with social self-concept. Besides, there is a moderate relation of mathematics achievement with LS, particularly with emotional control and with critical and creative thinking.

Provided that the variables that correlated with the outcome (i.e., mathematics achievement) are previous mathematics achievement, previous science achievement, attitude towards mathematics, attitude towards science, academic self-concept, social self-concept, emotional control strategies, and critical and creative thinking, the model was run with them as independent variables, and demographics as covariates. The results of the analysis are presented in Table 3, including odds ratio (OR) and the 95% confidence interval for each predictor. ORs reflect the increase (or decrease) in the odds of a participant being in the contrast group (passing grades) relative to the group who received failing scores in mathematics based on the change per unit for each predictor.

The results revealed that, on the one hand, there were significant differences between participants in the fail versus pass mathematics groups in science achievement, previous science achievement, previous mathematics achievement, critical and creative thinking, and school environment. Specifically, compared with participants who failed mathematics, the odds of being in the group who passed mathematics were higher for participants with higher science achievement, higher previous mathematics achievement, slightly lower previous science achievement, and higher scores on critical and creative thinking ($p = 0.016$, $p < 0.001$, $p = 0.028$, and $p = 0.004$, respectively). On the other hand, sex, type of school, attitude towards mathematics, attitudes towards science, academic self-concept, social self-concept, and emotional control LSs were not associated with failing or passing mathematics (all with $ps > 0.05$), with school environment being marginally significant ($p = 0.051$).

The Nagelkerke coefficient showed evidence that our model explained 55% (maximum likelihood) of the total variance among groups related to mathematics achievement and demonstrated significant differences on chi-squared distribution $\chi^2 = 101.130$, $p < 0.001$. Moreover, our model showed good performance in classifying participants accurately into the correct achievement group (see Table 4), with 82.6% of the participants correctly classified overall.

Table 2. Spearman's correlations between mathematics achievement and other variables of interest (* $p < 0.05$, ** $p < 0.001$; bilateral test).

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	1. Mathematics achievement	—														
	2. Science achievement	0.504 **	—													
	3. Previous mathematics achievement	0.783 **	0.447 **	—												
	4. Previous science achievement	0.565 **	0.726 **	0.631 **	—											
Attitude	5. Towards Mathematics	−0.488 **	−0.057	−0.360 **	−0.186 **	—										
	6. Towards Science	0.115 *	0.104 *	0.014	0.177 **	−0.064	—									
Self-concept	7. Academic	0.366 **	0.101	0.282 **	0.181 **	−0.291 **	0.169 **	—								
	8. Social	0.148 *	−0.076	0.094	0.016	−0.165 **	0.091	0.447 **	—							
	9. Physical	0.041	−0.081	−0.080	−0.068	−0.189 **	0.119 *	0.315 **	0.278 **	—						
	10. Personal	−0.009	0.060	−0.004	−0.063	−0.168 **	0.075	0.339 **	0.348 **	0.344 **	—					
	11. General	−0.080	−0.065	−0.062	−0.059	0.027	0.103 *	0.266 **	0.229 **	0.142 *	0.384 **	—				
Learning Strategies	12. Emotional control	0.258 **	0.055	0.273 **	0.161 **	−0.369 **	0.105 *	0.276 **	0.190 **	0.177 **	0.269 **	0.041	—			
	13. Critical and creative thinking	0.205 *	0.105	0.105	0.135 *	0.087	−0.122 *	0.421 **	0.300 **	0.067	0.245 **	0.082	0.105	—		
	14. Metacognition: Planning and evaluating	−0.073	−0.210 **	−0.167 **	−0.227 **	0.099	0.167 **	0.108	0.051	0.095	0.123 *	0.103	−0.058	0.128 *	—	
	15. Metacognition: Regulation	−0.013	−0.049	−0.065	0.015	0.055	0.033	−0.003	0.126 *	0.137 *	0.106	−0.011	0.013	0.128 *	−0.018	—

Table 3. Binomial logistic regression based on passing mathematics grades as a reference group.

	Mathematics Achievement		
	OR	95% CI	<i>p</i>
Science achievement	1.002 *	1.000–1.004	0.016
Previous mathematics achievement	2.690 *	1.922–3.763	<0.001
Previous science achievement	0.997 *	0.995–1.000	0.028
Attitude towards Mathematics	0.949	0.889–1.013	0.119
Attitude towards Science	1.001	0.978–1.025	0.926
Academic self-concept	1.090	0.978–1.215	0.118
Social self-concept	0.968	0.862–1.087	0.581
Emotional control learning strategies	0.974	0.872–1.087	0.632
Critical and creative thinking	1.120 *	1.038–1.209	0.004
Sex (M/F)	1.149	0.506–1.613	0.740
School environment (R/U)	0.215 a	0.046–1.007	0.051
School type (SFS/SS)	0.251	0.051–1.230	0.088

Note: * appears in all the statistically significant relationships, ^a appears in all the statistically marginal relationships.

Table 4. Classification table for the model.

	Predicted		
	Fail	Pass	Percentage Correct
Fail	61	18	77.2%
Pass	15	96	86.5%
Overall percentage			82.6%

4. Discussion

Based on the literature reviewed, the interrelationship between affective, cognitive, and behavioral variables could be predictive of mathematics achievement [26,27]. Therefore, the aim of this study was to determine the relationship between self-concept (physical, social, personal, academic, and general), LSs (emotional control, critical and creative thinking, and metacognition), attitude towards mathematics, and previous qualification in science and mathematics in the prediction of academic achievement in mathematics. In addition, the rural/urban environment, the type of school (state or state-funded), and sex were taken into account as covariates. For that purpose, a convenience sample of 352 pupils taking part in a STEM experimentation outreach program attending rural or urban SS or SFSs was analysed.

Regarding the mean values of variables in the fail versus pass mathematics achievement, these are higher for passing grades in the majority, while for the attitude towards mathematics, the attitude towards science, and planning and evaluating (metacognition), the mean values are smaller. These results were unexpected except in the case of the attitude towards mathematics, because a lower attitude means lower anxiety, which would be expected in passing grades [33].

The model yielded several predictors of mathematical achievement with higher odds for previous mathematics achievement, in such a way that the group with a higher mathematics achievement in the previous academic year had a 2.690 times greater chance of successfully passing a mathematical test in the current year than the other group. It seems that previous experiences of success in mathematics can be appraised by students as a scaffolding for learning, increasing the probability of successful mathematical performance, thus confirming a fundamental aspect in the present and future trajectory of students both academically and socially [2]. These positive past experiences not only affect achievement,

but also can promote a positive attitude towards mathematics, as indicated by various authors [22,25,26,28], although this attitude does not appear as a predictor in the present model. As shown by Di Martino and Zan [24], happy or unhappy past experiences with mathematics (i.e., failing or passing) can contribute to the creation of attitudes towards mathematics, resulting in a negative or positive predisposition towards the subject. Therefore, previous successful experiences could reinforce the development of a positive attitude towards mathematics, which is crucial for the effective tackling of mathematical tasks [56], while our findings did not support it. Therefore, more research is needed.

The STEM literature shows the fields of science and mathematics to be interrelated, as noted by some authors [16] who emphasize that learning activities that connect science and mathematics can increase academic achievement in mathematics. In the present model, not only the current science achievement, but also the previous science achievement are predictors of mathematics achievement. Nonetheless, the ORs are close to 1 in both cases, providing no real influence on the passing or no passing grade in mathematics achievement.

The correlation found in this study between academic results in science and mathematics and academic self-concept confirms the two-way relationship between both variables, confirming the findings in the literature [8,39], although academic self-concept is not a predictor in the evaluated sample.

Although prior knowledge is important, LSs play an important role in the teaching–learning process in mathematics, and thus in mathematics achievement, as LSs involve the way in which the subject tasks are approached. In our model, the use of critical and creative thinking approaches increases the chance of success in mathematical tasks by 1.120. That is, an approach based on application, effort, the contrast of ideas, and innovation in facing academic tasks may be associated with adaptation to various situations, and thus with cognitive flexibility, promoting the development of mathematical skills. The association found between creative thinking and cognitive flexibility in the mathematical field has been noted by some authors [44,45], as well as the fact that higher achievers in mathematics do use to a higher extent critical and creative thinking [49]. Nonetheless, more research is needed as claimed by Clements et al. [46], who considered the assumption that LSs are positively associated with instruction that allows for experimentation and conceptual deepening in mathematics learning through problem solving.

Although the attitude towards mathematics plays an important role regarding achievement, not only in mathematics, but also in science, which is supported in this study by the intense correlations with the current and previous mathematics achievement, and a less intense correlation with the science achievement (see Table 2), it is not acting as a predictor of mathematics achievement in the model. The correlations are negative, which is expected because the attitude is rather measuring anxiety in the scale used. In this sense, the anxiety is related to the affective component of the attitude towards mathematics and to emotional control as a coping strategy. In the present study, several correlations are found that open the necessity for wider research in this vein, such as the moderate and significant correlation between academic, social, physical, and personal self-concept, as well as the moderate significant correlation with emotional control and the intense correlation with mathematics achievement. These findings emphasize the need to determine the importance of emotional management, specifically of anxiety, when facing mathematical tasks, which is an aspect highlighted in the literature [30] and needing deeper research.

As for metacognition (planning and evaluating, and regulation), our results are in line with those of Palacios et al. [33] in such a way that it is not a predictive variable of mathematics achievement. Perhaps the lack of predictive capacity observed may be due to the fact that mathematical competences are developed through an excessively mechanical daily practice, without encouraging students to carry out metacognitive processes oriented towards planning or evaluating previous knowledge [12], or without students being aware that they are using these cognitive skills, at least. Future studies should thus use more specific tools to evaluate cognitive processes in mathematics.

Regarding the covariates, neither sex nor type of school (SS/SFS) were associated with mathematics achievement. The result on sex was aligned with [6], who investigated Chinese and United States students. Regarding school type, the SFSs are settled in urban areas rather than in rural ones, and it was found that mathematics achievement was higher in urban than in rural schools. As in [4–6], it is expected to detect an influence of sociocultural factors in mathematics achievement, but it is not found in the literature, and neither in this study, so more research is needed to confirm or discard this influence.

The results of the influence of critical and creative thinking on mathematics achievement do have some implications for mathematics education, as it will be worth encouraging creative solutions to mathematical tasks, which could guarantee higher success. In this respect, for instance, Weber et al. [58] said that creativity is useful to solving everyday problems, which would be connected to mathematical competence, provided that both are needed to solve everyday problems. Although in most countries, mathematical competence is proposed to be developed through the affordance of everyday problems, only in some countries are creative thinking skills part of the curricula [59]. Evidence exists about the fact that the teaching approach influences the development of creative thinking and the ability to solve problems in mathematics [60], fostering the development of practices that involve open-ended problems [61] or realistic mathematics [62]. On the other side, a consensus exists on the fact that neither creativity nor mathematical competence are fostered through teaching practices based on algorithms or memorization. Therefore, more research is needed to discover the contribution of the different teaching approaches to the promotion of creativity in mathematics [63]. Meanwhile, this paper sheds light to some extent provided that the creation of pass/fail groups allows to contrast possible differences in cognitive and emotional variables that accompany the process of mathematical learning. Future studies might introduce cognitive variables such as the perceived self-efficacy in mathematical tasks as well as deepen the research on creative potential in relation to logical-mathematical thinking. Besides, as for school environment and teaching practices, it would be appropriate to evaluate achievement with students exposed to different methodologies, fundamentally manipulative versus traditional methodologies. Finally, we are sure that a longitudinal experimental design will make it possible to learn how critical and creative thinking evolves in relation to mathematical skills' development among young students.

This study has limitations that should be taken into account when interpreting the results. Among them, the use of a convenience sample, although similar to the regional student population, prevents the generalization of the results, as does the lack of control over some foreign variables. Another limitation can be the use of students' self-reports for students' achievement, which, although supervised by teachers, would depend on the teachers' subjective assessment and on the indicators considered for that assessment. Therefore, the choice of a common test to measure achievement for all the participants could contribute to minimizing the possible teacher bias. However, the model provides novel confirmation of the predictive character of previous achievement in science and mathematics for the present and future success in mathematical tasks and that students perform these tasks better in urban schools. In this vein, as indicated in the introduction, there is a lack of literature regarding the possible influence of school environments on mathematics achievement, so these results contribute to filling a research gap. Likewise, this last factor can be interpreted from the perspective of the importance of the cultural environment in the construction of knowledge [4]. However, it must be investigated in further studies to deepen our understanding of it.

Author Contributions: Conceptualization, N.S.-P. and R.F.-C.; methodology, R.F.-C. and N.S.-P.; formal analysis, D.G.; investigation, R.F.-C., N.S.-P. and D.G.; data curation, D.G. and N.S.-P.; writing—original draft preparation, R.F.-C.; writing—review and editing, N.S.-P. and D.G.; visualization, R.F.-C.; supervision, R.F.-C.; project administration, R.F.-C.; funding acquisition, N.S.-P. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the Spanish Foundation of Science and Technology, FECYT, grant number FCT-16-10952, and Castilla La Mancha University, grant number 2019-GRIN-27083.

Data Availability Statement: Data can be available on request to correspondence author.

Conflicts of Interest: The authors declare no conflict of interest.

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