

# Early Literacy and Numeracy Competencies: Predictors of Mathematics Achievement in the Dinaric Region



Ženeta Džumhur, Nada Ševa, and Mojca Rožman

**Abstract** Studies have indicated that early literacy (EL) and early numeracy (EN) competencies are strong predictors of later mathematical performance in school. Data from IEA's Trends in International Mathematics and Science Study (TIMSS) 2019, together with comprehensive exploration of regional similarities and differences between education systems, confirm that students' preschool EL and EN competencies are important predictors of mathematics achievement among grade four students from the Dinaric region. This applies for all content domains specified in the TIMSS 2019 mathematics framework: numbers, measurement and geometry, and data. Although TIMSS 2019 parental reports for the different EL and EN tasks varied considerably across the region, children in the Dinaric region who could recognize letters, write numbers, or count independently before starting school tended to achieve higher scores on the mathematics tasks in TIMSS 2019. This confirms that EL and EN skills have a strong relationship with later school outcomes in mathematics. Recognition of these findings could provide the basis for changes in the preschool curriculum and further development of programs for parents/guardians on numeracy development.

**Keywords** Early literacy · Early numeracy · Grade four education · International large-scale assessments (ILSA) · Mathematics achievement · Parental reports · Trends in International Mathematics and Science Study (TIMSS)

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## 1 Introduction

Early literacy and numeracy competencies relate to the set of knowledge and skills developed during the preschool period. Early literacy (EL) includes the knowledge and abilities linked to language (vocabulary, background knowledge, semantics, and communication skills), print awareness (alphabet, and concepts about print), and phonological awareness (rhyme, alliteration, segmentation, and blending) (Rohde, 2015). Early numeracy (EN) is a term that encompasses several skills, such as verbal counting, knowing number symbols, recognizing quantities, discerning number patterns, comparing numerical magnitudes, and manipulating quantities (i.e., adding and subtracting objects from a set) (Raghubar & Barnes, 2017). EL and EN competencies, as a part of a school readiness construct, have been demonstrated to be strong predictors of mathematical achievement in school (Duncan et al., 2007; Melhuish et al., 2008; Nguyen et al., 2016).

It is important to emphasize that both EL and EN are set in the context of cultural, demographic, and community characteristics. Thus, they can be viewed as an interactive process of skills and context rather than a linear series of individual components (Rohde, 2015). Numerous studies have confirmed this theoretical stance, indicating that children's exposure to literacy and numeracy experiences in the preschool period may be positively correlated with their early literacy and numeracy competencies (Gustafsson et al., 2013; LeFevre et al., 2009; Skwarchuk et al., 2014). It is suggested that several factors account for this effect: socioeconomic status (SES) of families, number of years spent in kindergarten, home resources related to language and mathematical competencies, parental preschool literacy and numeracy practices, and parental attitudes toward mathematical development and schooling in general (Zippert & Rittle-Johnson, 2020). Cultural differences can play an important role in the quality of home numeracy experiences (Aunio et al., 2004; Lefevre et al., 2002). They are usually associated with sociological differences, such as perceived value of education and knowledge in general, educational policies, and parents/guardians' perceptions related to whether children should be learning through school-like activities in early childhood, as well as linguistic differences in the way numeral systems are represented (Cankaya & LeFevre, 2016). In addition, parental attitudes and beliefs about their own, as well as their children's mathematical competencies, can influence the nature of the early learning experiences they provide (Hart et al., 2016; Zippert & Ramani, 2017).

In the context of large-scale assessment studies like IEA's Trends in International Mathematics and Science Study (TIMSS) and Progress in International Reading Literacy Study (PIRLS), recent cycles have indicated that early learning activities can help to lay the foundation for positive schooling outcomes in the future (Meinck et al., 2018). Results from TIMSS 2011 for European Union (EU) countries showed that EL and EN competencies were related to subsequent success in mathematics (Soto-Calvo & Sánchez-Barrioluengo, 2016). Nevertheless, the strength of the prediction varied across the countries, as well as the size of the effect of early numeracy compared to early literacy competencies.

## 2 Purpose of the Study and Research Questions

Seven participants from the Dinaric region took part in TIMSS 2019, namely Albania, Bosnia and Herzegovina, Croatia, Kosovo,<sup>1</sup> Montenegro, North Macedonia, and Serbia. Given the importance of social and cultural diversities, our aim was to extend research into the value of developing early competencies using TIMSS 2019 data for participants from the Dinaric region. A previous study into early numeracy experiences in Serbia from TIMSS 2015 showed that the variables related to providing a supportive home environment for learning (home resources for learning, early literacy and numeracy activities, preprimary education, early literacy and numeracy tasks; (see Mullis et al. 2016) explained more than a quarter of the variance in student achievement at grade four (Radišić & Ševa, 2017). They found that availability of home resources for learning proved to be the strongest predictor of achievement, followed by a variable based on parents'/guardians' assessment of their child's mathematical competencies before starting school, and kindergarten attendance. We based our research design on that used for a study of EU countries undertaken by Soto-Calvo and Sánchez-Barrioluengo (2016). Using this design enabled us to follow the trends in the relation between EN/EL competencies and mathematics achievement in Dinaric region in a comparable manner.

Our work was guided by three key research questions:

- (1) *Do students from Dinaric region exhibit regional differences in early numeracy and literacy competencies?*
- (2) *To what extent is student performance in mathematics at grade four related to early literacy and numeracy competencies, and, in particular, related to the tasks from number content domain?*
- (3) *Are there any gender differences in levels of early literacy and numeracy competencies, and are those differences reflected in student mathematics achievement at grade four?*

## 3 Variables

The predictor variables used in this study are the composite variables early literacy tasks (ELT) and early numeracy tasks (ENT). These variables represent parental estimation of their children's competencies before entering the first grade of primary school regarding their early literacy and early mathematical competencies, collected retrospectively when the students were in grade four through the TIMSS 2019 Early Learning Survey (also referred to as the home questionnaire; TIMSS & PIRLS International Study Center, 2018). We also used parental reports of single literacy and numeracy tasks to explore specific characteristics of students' preschool competencies in more detail (Table 1).

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<sup>1</sup> All references to Kosovo in this document should be understood to be in the context of United Security Council resolution 1244 (1999).

**Table 1** List of variables used in analyses

Variable	Description	Values/Response options	Reference
Early literacy tasks scale <sup>a</sup>	<p>Parents' responses on how well their child could do the following when he/she began the first grade of primary/elementary school:</p> <ul style="list-style-type: none"> <li>• Recognize most of the letters of the alphabet</li> <li>• Read some words</li> <li>• Read sentences</li> <li>• Read a story</li> <li>• Write letters of the alphabet</li> <li>• Write his/her name</li> </ul> <p>Response options: very well, moderately well, not very well, not at all</p>	<p>The higher the score the higher the student's competency in performing early literacy tasks, as assessed by their parents/guardians</p> <p>Index: Very well, Moderately well, Not well</p>	Martin et al. (2020, p. 16.32)
Early numeracy tasks scale <sup>a</sup>	<p>Parents' responses if their child could do the following when he/she began the first grade of primary/elementary school</p> <ul style="list-style-type: none"> <li>• Count by himself/herself</li> <li>• Recognize written numbers</li> <li>• Write numbers</li> </ul> <p>Response options: up to 100 or higher, up to 20, up to 10, not at all</p> <ul style="list-style-type: none"> <li>• Do simple addition</li> <li>• Do simple subtraction</li> </ul> <p>Response options: Yes, no</p>	<p>The higher the score the higher the student's competency in performing early numeracy tasks, as assessed by their parents/guardians</p> <p>Index: Very well, Moderately well, Not well</p>	Martin et al. (2020, p. 16.32)

(continued)

The dependent variable was student achievement in mathematics and its content subdomains (number, measurement and geometry, and data) in TIMSS 2019. The following variables were used as control variables in regression models: attendance in preschool programs (recoded into “no attendance,” “less than three years,” and “three years or more”), student gender, and the TIMSS home resources for learning scale (Table 1).

**Table 1** (continued)

Variable	Description	Values/Response options	Reference
Home resources for learning scale <sup>a</sup>	Based on students' and parents' reports regarding the availability of five resources: <ul style="list-style-type: none"> <li>• Number of books in the home (students)</li> <li>• Number of home study support (students)</li> <li>• Number of children's books in the home (parents)</li> <li>• Highest level of education of either parent (parents)</li> <li>• Highest level of occupation of either parent (parents)</li> </ul>	Higher values mean more home resources Index: Many resources, Some resources, Few resources	Martin et al. (2020, p. 16.39)
Student gender	Information on students' gender provided by students	Boy Girl	Fishbein et al. (2021, Supplement 1, p. 11)
Attendance in preschool programs	How long was your child visiting early childhood or pre-primary educational program	Did not attend Less than 1 year 1 year 2 years 3 years 4 years or more	Fishbein et al. (2021, Supplement 1, p. 45)

*Note*<sup>a</sup>These TIMSS scales are constructed so that the scale center point of 10 is located at the mean score of the combined distribution of all TIMSS 2019 grade four participants. The units of the scale are chosen so that the standard deviation of the distribution corresponds to two scale score points

We analyzed data using basic and advanced methods to estimate percentages, means, correlations, and develop regression models. We conducted all statistical computations using established standard procedures for data from large-scale assessments (see Sect. 5 for more details on the analysis methods and tools that we used).

## 4 Results

### 4.1 Similarities and Differences in Students' Early Numeracy and Literacy Competencies Across the Dinaric Region

We derived average scale scores for the composite variables ELT and ENT from the TIMSS 2019 data for the education systems from the Dinaric region (Table 2). According to Mullis et al. (2020), these average scale scores indicate that children in the Dinaric region could do, on average, most early literacy and numeracy tasks moderately well.

#### *Early Literacy Competencies Across the Dinaric Region*

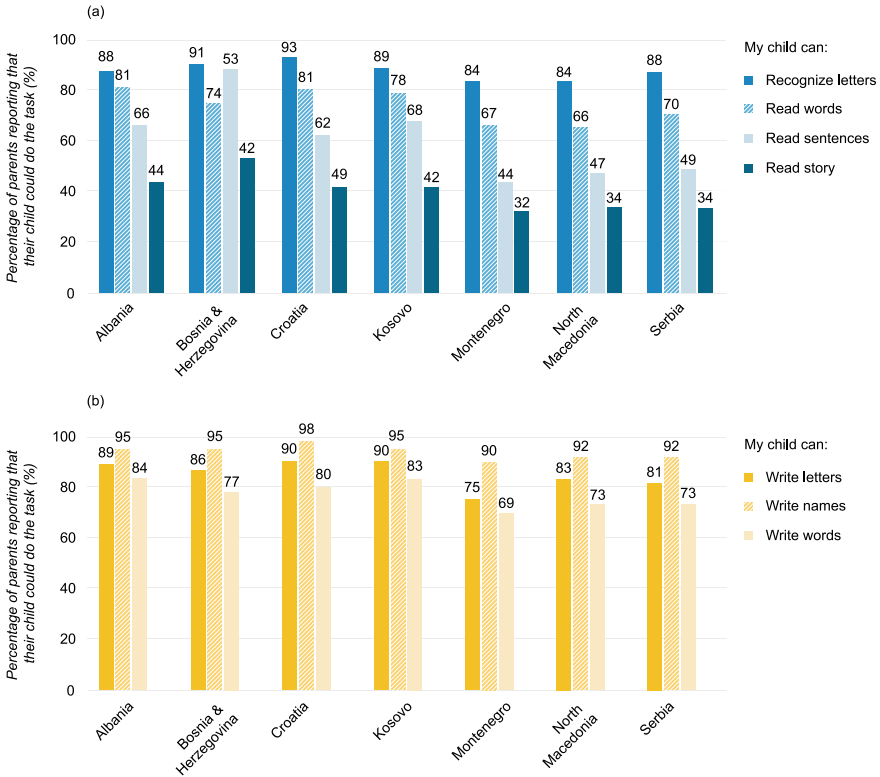
In order to further explore the variation in early competencies, we investigated the percentages of students in the Dinaric region who, according to their parents/guardians, were able to perform specific early literacy tasks “very well” or “moderately well” (Fig. 1). The vast majority of parents/guardians reported that their child could write their name (>90% across the region), and more than 80% of students could recognize and write letters before attending school (with the exception of Montenegro). Far fewer children could perform more advanced activities, like reading words, sentences, or even stories, or writing words. It is understandable that fewer students mastered skills like reading stories before starting formal schooling, since pre-reading skills for children aged four to five are associated with recognizing syllables as well as the first and last letters in a word (Čudina-Obradović, 2002). In addition, children of this age group are usually emerging from the scribble stage of development when their writing begins to look like real letters and words, combined with shapes that are visually similar to displaced and valid letters (Baucal, 2012; Hope, 2008).

**Table 2** Average scale scores for composite variables early literacy tasks (ELT) and early numeracy tasks (ENT)

Education system	Average score on the ELT scale		Average score on the ENT scale	
	Score	SE	Score	SE
Albania	10.7	(0.07)	10.6	(0.07)
Bosnia & Herzegovina	10.2	(0.03)	9.7	(0.04)
Croatia	10.6	(0.04)	10.4	(0.05)
Kosovo <sup>a</sup>	10.7	(0.04)	10.5	(0.05)
Montenegro	9.8	(0.03)	9.6	(0.03)
North Macedonia	10.0	(0.05)	10.2	(0.06)
Serbia <sup>a</sup>	10.0	(0.04)	10.0	(0.05)

Notes Standard errors appear in parentheses

<sup>a</sup>National defined population covers 90–95% of the national target population

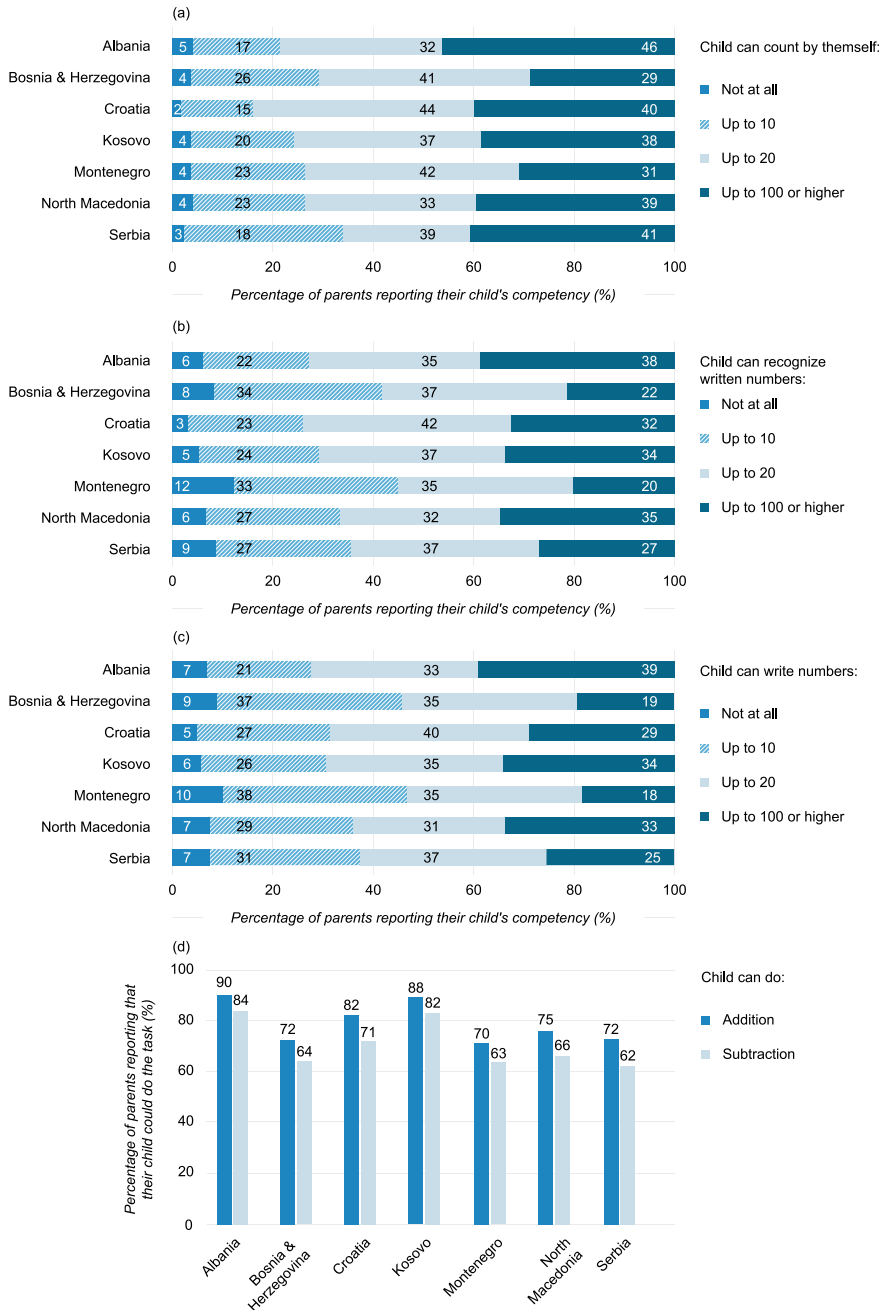


**Fig. 1** Percentage of parents in the Dinaric region who reported that their child could do the **a** reading and **b** writing tasks “very well” or “moderately well” in response to the TIMSS 2019 Early Learning Survey Notes In Kosovo and Serbia, the national defined population covers 90–95% of the national target population. In North Macedonia, data were available for  $\geq 70\%$  of students, but  $< 85\%$  of students

Among the education systems from the Dinaric region, there was large variation in the percentages of parents reporting that their child was able to perform the activities related to reading and writing words, sentences, or stories (Fig. 1). Two distinct groups could be distinguished among the participating entities: parents/guardians in Albania, Bosnia and Herzegovina, Croatia, and Kosovo tended to report that their children had acquired relatively high literacy competencies during the preschool period, especially regarding reading sentences and stories, while slightly lower percentages of parents/guardians in Montenegro, North Macedonia, and Serbia said that their children had acquired these cognitively demanding skills before entering school (Fig. 1).

*Early Numeracy Competencies Across the Dinaric Region*

According to their parents/guardians’ reports, few students were unable to count by themselves before entering school (Fig. 2). Similar results were reported for the skills



**Fig. 2** Percentage of parents reporting that their child could **a** count by himself/herself, **b** recognize written numbers, **c** write numbers, and **d** add or subtract numbers *Note* In Kosovo and Serbia, the national defined population covers 90–95% of the national target population



of recognizing or writing numbers, with the exception of Montenegro, which reported higher percentages of children entering the school system with no demonstrated ability to recognize and write numbers (12% and 10%, respectively). Recognizing and writing numbers over 20 was more challenging for preschoolers; only approximately a third of parents/guardians across the region reported their children had developed those skills. The variation among participants from the Dinaric region was also pronounced for these two categories (Fig. 2); for example, the results from Albania and Montenegro differ by approximately 20%.

Regarding the more advanced numeracy skills, such as addition and subtraction, parents/guardians' reports suggested that, on average, 79% of the children in the region were able to do addition, while 70% could do subtraction. However, again there was some variation between participating systems; for instance, there was an almost 20% point difference between Albania and Bosnia and Herzegovina (Fig. 2).

For preschoolers, writing numbers is the hardest task of all listed early numeracy tasks. Children must be capable of reproducing a graphical representation of the number without fully understanding the relationship between the symbol and concept of quantity behind it. At the same time, the development of counting is happening automatically, possibly due to the high number of traditional counting rhymes that exist in the Dinaric region.

An interesting finding for students from the Dinaric region is that as many children mastered addition as mastered counting. Acquired symbolic number, namely an understanding of the concept of the cardinality principle, as well as more highly developed counting skills (the ability to count up to 100 by the age of six) have been shown to be good indicators of later arithmetic skills (Göbel et al., 2014; Muldoon et al., 2013). It is extraordinary to find that most parents/guardians in the Dinaric region reported that, alongside abilities to count up to and beyond 20, children possessed higher or very similar values for skills related to addition. This suggests that children are capable of performing both activities at the same level. However, closer inspection of the wording of the survey question (TIMSS & PIRLS International Study Center, 2018) might provide another explanation; it could have been more specific and it did not fully define "simple addition." Although memorization of addition expressions from children's nurseries could be considered an indicator of arithmetic skills development, we note that models of numeracy development predict several competences/skills are developed (symbolic number system, estimation of quantity without counting, comparison, approximation and numerical magnitudes, and counting strategies) before children are able to personally implement "simple" written calculations or other arithmetic skills (LeFevre et al., 2010; Siegler & Braithwaite, 2017; Von Aster & Shalev, 2007).

## ***4.2 Relating ELT and ENT to Mathematics Achievement***

We first determined whether the predictor variables (ELT and ENT) and achievement were related using correlation analysis (Table 3). We found that both EL and

**Table 3** Correlations between parents/guardian assessments of children's early literacy and numeracy competencies and their TIMSS 2019 mathematics achievement

Education system	Correlation between ELT and mathematics achievement		Correlation between ENT and mathematics achievement	
Albania	<b>0.30</b>	(0.03)	<b>0.24</b>	(0.03)
Bosnia & Herzegovina	<b>0.19</b>	(0.02)	<b>0.29</b>	(0.02)
Croatia	<b>0.30</b>	(0.02)	<b>0.33</b>	(0.02)
Kosovo <sup>a</sup>	<b>0.15</b>	(0.02)	<b>0.22</b>	(0.02)
Montenegro	<b>0.22</b>	(0.02)	<b>0.29</b>	(0.02)
North Macedonia	<b>0.19</b>	(0.03)	<b>0.29</b>	(0.02)
Serbia <sup>a</sup>	<b>0.36</b>	(0.02)	<b>0.40</b>	(0.02)

Notes ELT = early literacy tasks, ENT = early numeracy tasks. Statistically significant ( $p < 0.05$ ) correlation coefficients are shown in bold. Standard errors appear in parentheses

<sup>a</sup>National defined population covers 90–95% of the national target population

EN competencies were significantly correlated with achievement in all participating entities. However, correlations varied considerably; Serbia had the highest correlation coefficient (0.36) and Kosovo the lowest coefficient (0.15).

We applied three regression models to explore to what extent the composite variables ENT and ELT predicted mathematics achievement (either separately and/or in combination), controlling for variables related to students' individual characteristics such as gender, home resources for learning, and preschool attendance:

- (1) *Model 1* ENT (early numeracy tasks);
- (2) *Model 2* ELT (early literacy tasks);
- (3) *Model 3* ELT + ENT (early literacy tasks + early numeracy tasks).

We found that these variables were significant predictors of mathematics achievement in the Dinaric region (Table 4). This was generally true for all three models, with only one exception (North Macedonia, model 3). The models explained considerable amounts of variation in achievement; for example, in Model 1 for Albania, 19% of the variation in mathematics achievement of grade four students could be explained by the model. Positive values for standardized coefficients indicated positive relationships between ELT/ENT and achievement. It should be noted that values for the variance explained ( $R^2$ ) varied across the region. The lowest were observed for Kosovo, Albania, and Bosnia and Herzegovina, and the highest for North Macedonia and Serbia (Table 3). In assessing the relative importance of predictor variables within the models, standardized regression coefficients were significant for each education system for models 1 and 2, but varied across the Dinaric region (Table 4). In model 3, the regression coefficients of ENT were higher than those for ELT in Bosnia and Herzegovina, Kosovo, and North Macedonia, and the 95% confidence intervals between the two scales did not overlap, suggesting that the coefficients for these participants differed. However, this did not hold in Albania, Croatia, Montenegro, and Serbia. This implies that, in the three systems where the regression coefficients for

**Table 4** Amount of variance in students' mathematics achievement explained by the models, and standardized regression coefficients for early numeracy and early literacy tasks, after controlling for background characteristics (home resources for learning, preschool attendance, and gender)

Education system	Model 1 (ENT variables)			Model 2 (ELT variables)			Model 3 (ENT + ELT variables)			
	<i>n</i>	<i>R</i> <sup>2</sup>	ENT	<i>n</i>	<i>R</i> <sup>2</sup>	ELT	<i>n</i>	<i>R</i> <sup>2</sup>	ELT	ENT
Albania	3835	0.19	<b>0.14</b>	3800	0.20	<b>0.18</b>	3796	0.20	<b>0.14</b>	<b>0.08</b>
Bosnia & Herzegovina	5003	0.18	<b>0.24</b>	4933	0.16	<b>0.19</b>	4927	0.19	<b>0.10</b>	<b>0.19</b>
Croatia	3596	0.20	<b>0.26</b>	3592	0.20	<b>0.27</b>	3591	0.23	<b>0.18</b>	<b>0.17</b>
Kosovo <sup>a</sup>	3749	0.13	<b>0.18</b>	3638	0.11	<b>0.12</b>	3634	0.13	<b>0.06</b>	<b>0.16</b>
Montenegro	3852	0.18	<b>0.24</b>	3798	0.17	<b>0.21</b>	3789	0.19	<b>0.13</b>	<b>0.17</b>
North Macedonia	2539	0.27	<b>0.19</b>	2511	0.25	<b>0.13</b>	2502	0.27	0.05	<b>0.17</b>
Serbia <sup>a</sup>	4151	0.33	<b>0.27</b>	4123	0.31	<b>0.24</b>	4120	0.34	<b>0.15</b>	<b>0.19</b>

*Notes:* Statistically significant ( $p < 0.05$ ) regression coefficients are shown in bold. Standard errors appear in parentheses. *n* = the number of students included in the regression mode, *R*<sup>2</sup> = the proportion of variance in achievement explained by the stated independent variable (ELT, ENT or ENT + ELT) including the background variables (home resources for learning, preschool attendance and gender)

<sup>a</sup>National defined population covers 90–95% of the national target population

ENT were higher, ENT was a more powerful predictor of mathematics achievement than ELT, when accounting for both measures.

Our analyses indicated that the relative contributions of home resources for learning, student gender, and preschool attendance toward student achievement varied across all three models (Tables 5, 6 and 7). As expected, home resources were found to be a more consistent significant predictor of mathematics achievement than the predictor variables ENT, ELT or ELT + ENT, respectively (i.e., the regression coefficients were larger, indicating a larger association or relationship; Cohen et al., 2003). The regression coefficients for home resources remained similar across participating systems in all our analyses, although regression coefficients were notably larger for North Macedonia and Serbia than for other systems. Conversely, gender and length of preschool attendance (<3 years, or  $\geq 3$  years) were less important contributors for all three models.

The negative regression coefficients for gender imply that boys tended to have higher mathematics achievement than girls, after controlling for all other factors included in this model. However, our analyses revealed that gender had very little impact on achievement in Bosnia and Herzegovina, Croatia (Model 1–3), Montenegro (Models 2–3), and Serbia (Model 2), and no significant impact in other systems and models. Preschool attendance was also shown to be a weak predictor of mathematics achievement. Our research only identified significant regression coefficients related to <3 years preschool attendance in Kosovo (Model 1–3) and in Bosnia and Herzegovina (Model 3). Equally, regression coefficients were low, but significant for preschool attendance of three years or longer in only Kosovo and North Macedonia.

**Table 5** Standardized regression coefficients for the control variables in Model 1 (ENT)

Education system	Home resources for learning scale		Gender (girl)		Preschool attendance (<3 years)		Preschool attendance ( $\geq 3$ years)	
		(0.03)		(0.02)				
Albania	0.36	(0.03)						
Bosnia & Herzegovina	0.31	(0.02)	-0.06	(0.02)				
Croatia	0.29	(0.03)	-0.09	(0.02)				
Kosovo <sup>a</sup>	0.26	(0.03)			0.08	(0.03)	0.06	(0.03)
Montenegro	0.30	(0.02)						
North Macedonia	0.40	(0.03)					0.08	(0.04)
Serbia <sup>a</sup>	0.40	(0.02)						

*Notes* Only statistically significant ( $p < 0.05$ ) regression coefficients are shown, empty cells indicate values were not significant. Standard errors appear in parentheses

<sup>a</sup>National defined population covers 90–95% of the national target population

**Table 6** Standardized regression coefficients for the control variables in Model 2 (ELT)

Education system	Home resources for learning scale		Gender (girl)		Preschool attendance (<3 years)		Preschool attendance (≥3 years)	
Albania	0.34	(0.03)						
Bosnia & Herzegovina	0.33	(0.02)	-0.09	(0.02)				
Croatia	0.30	(0.02)	-0.14	(0.02)				
Kosovo <sup>a</sup>	0.26	(0.03)			0.07	(0.03)	0.06	(0.03)
Montenegro	0.32	(0.02)	-0.06	(0.02)				
North Macedonia	0.42	(0.03)					0.08	(0.04)
Serbia <sup>a</sup>	0.41	(0.02)	-0.05	(0.02)				

*Notes* Only statistically significant ( $p < 0.05$ ) regression coefficients are shown, empty cells indicate values were not significant. Standard errors appear in parentheses

<sup>a</sup>National defined population covers 90–95% of the national target population

**Table 7** Standardized regression coefficients for the control variables in Model 3 (ENT + ELT)

Education system	Home resources for learning scale		Gender (girl)		Preschool attendance (<3 years)		Preschool attendance (≥3 years)	
Albania	0.34	(0.03)						
Bosnia & Herzegovina	0.31	(0.02)	-0.07	(0.02)	-0.05	(0.03)		
Croatia	0.28	(0.03)	-0.12	(0.02)				
Kosovo <sup>a</sup>	0.25	(0.03)			0.07	(0.03)	0.06	(0.03)
Montenegro	0.30	(0.02)	-0.04	(0.02)				
North Macedonia	0.40	(0.03)					0.07	(0.04)
Serbia <sup>a</sup>	0.37	(0.02)						

*Notes* Only statistically significant ( $p < 0.05$ ) regression coefficients are shown, empty cells indicate values were not significant. Standard errors appear in parentheses

<sup>a</sup>National defined population covers 90–95% of the national target population

### *The ENT Variable and Content Domains*

Given that the ENT variable was shown to be a relatively strong predictor of mathematics achievement for the Dinaric region in TIMSS 2019, we investigated the extent to which ENT predicated achievement could be attributed to the different content domains covered in TIMSS 2019 (number, measurement and geometry, and data). As in our previous regression models, variables related to home resources for learning, preschool attendance, and gender were used as controls.

Three regression models were used to evaluate this question with different dependent variables:

- (1) *Model number*: student achievement in the subdomain “number” predicted by ENT and control variables;
- (2) *Model measurement and geometry*: student achievement in the subdomain “measurement and geometry” predicted by ENT and control variables;
- (3) *Model data*: student achievement in the subdomain “data” predicted by ENT and control variables.

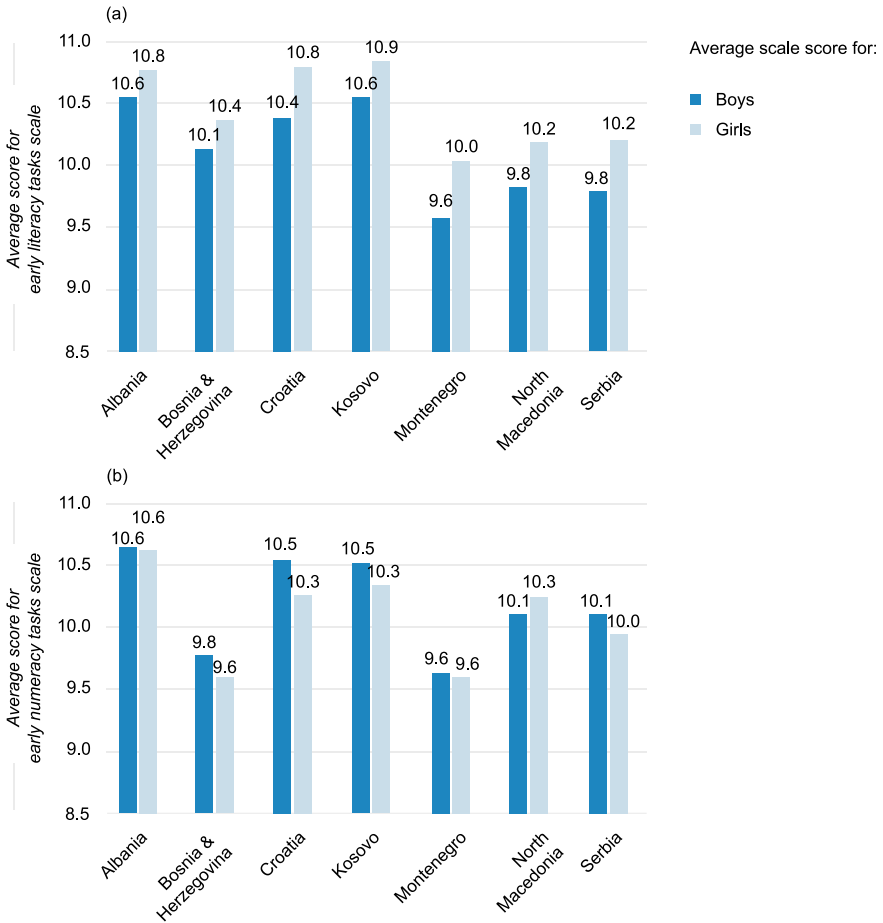
We found that ENT significantly predicted achievement not only for numeracy tasks, but also for measurement and geometry, and data tasks (see Tables S.5, S.6 and S.7 in the supplementary materials available for download at [www.iea.nl/publications/RFEVol13](http://www.iea.nl/publications/RFEVol13)). As we already noted for the relation between ENT and the overall achievement scores in mathematics for TIMSS 2019, the proportion of variance and regression coefficients were highest for Serbia, followed by North Macedonia. The explained variance ranged from 20 to 38% in all three cognitive domains; there was also a high correlation for the “number” domain in Croatia and Bosnia and Herzegovina, explaining up to 21% of the variance. Taking control variables into consideration, we observed patterns that were broadly similar to those obtained for Models 1–3, with home resources remaining a significant factor for all three models and for all Dinaric TIMSS participants. Gender and preschool attendance were also weakly significant, but had only low impact in a few instances across the Dinaric region.

### 4.3 Gender Differences

Gender differences in estimates of ELT skills were significant for all participants from the Dinaric region in favor of girls (Fig. 3). Estimates for girls’ ELT skills ranged from 10.0 in Montenegro to 10.9 in Kosovo (the average estimate for girls in the Dinaric region was 10.5). Estimates for boys’ ELT skills ranged from 9.6 in Montenegro to 10.6 in Albania and Kosovo (the average estimate for boys in Dinaric region was 10.1).

In contrast, differences between girls and boys were smaller for ENT than for ELT skills. Significant differences were found in only three of the participating systems; all favored boys, but these differences were not as pronounced as the consistent gender difference observed for the ELT variable. Estimates for girls ENT skills ranged from 9.6 in Montenegro to 10.6 in Albania (the average estimate for girls in the Dinaric region was 10.1). Estimates for boys’ ENT skills ranged from 9.6 in Montenegro to 10.6 in Albania (the average estimate for boys in Dinaric region was 10.2).

When assessing the relations between ELT and ENT estimates and mathematics achievement by gender, correlation analyses showed significant, but weak to moderate positive associations among those variables (Table 8), indicating that



**Fig. 3** Difference in parents/guardians’ assessment of their child’s **a** preschool literacy competency and **b** preschool numeracy competency by gender *Notes* Differences were statistically significant ( $p < 0.05$ ) in all participating education systems for the early literacy tasks, but only statistically significant in Bosnia and Herzegovina, Croatia, and Kosovo for the early numeracy tasks. In Kosovo and Serbia, the national defined population covers 90–95% of the national target population

higher ELT/ENT scores were related to better achievement on average across all students.

Overall, the correlation coefficients for ELT, both for girls and boys, tended to be lower than the correlation coefficients for ENT, but the differences were largest in Bosnia and Herzegovina and North Macedonia (average  $ELT_{boys} r = 0.26$ ,  $ELT_{girls} r = 0.24$ , compared to average  $ENT_{boys} r = 0.31$ ,  $ENT_{girls} r = 0.28$ ). For the ELT variable, two TIMSS participants attained moderate coefficients for both girls and boys (Serbia and Croatia). For the ENT variable, Albania, Kosovo, and North Macedonia had correlation coefficients of  $< 0.3$  for both boys and girls (indicating there were only

**Table 8** Correlations between parents/guardian assessments of children’s early literacy and numeracy competencies and their TIMSS 2019 mathematics achievement, by gender

Education system	Correlation coefficient between ELT and mathematics achievement				Correlation coefficient between ENT and mathematics achievement			
	Boys		Girls		Boys		Girls	
Albania	0.31	(0.04)	0.29	(0.03)	0.28	(0.04)	0.21	(0.03)
Bosnia & Herzegovina	0.20	(0.03)	0.19	(0.02)	0.30	(0.02)	0.26	(0.02)
Croatia	0.32	(0.03)	0.32	(0.03)	0.34	(0.03)	0.30	(0.03)
Kosovo <sup>a</sup>	0.16	(0.03)	0.14	(0.03)	0.23	(0.02)	0.21	(0.02)
Montenegro	0.24	(0.02)	0.21	(0.03)	0.31	(0.02)	0.27	(0.03)
North Macedonia	0.19	(0.04)	0.17	(0.04)	0.29	(0.03)	0.29	(0.03)
Serbia <sup>a</sup>	0.39	(0.03)	0.34	(0.03)	0.41	(0.03)	0.40	(0.03)

Notes All correlation coefficients were statistically significant ( $p < 0.05$ ). Standard errors appear in parentheses

<sup>a</sup>National defined population covers 90–95% of the national target population

small associations between variables according to Cohen’s standard for evaluation; see Cohen et al., 2003), while in Croatia and Serbia, the correlation coefficients were  $>0.3$  for both girls and boys (indicating only moderate correlations existed).

## 5 Discussion and Conclusions

We aimed to examine the relationship between early literacy and numerical competencies for grade four students in the Dinaric region and their subsequent mathematics achievement in the TIMSS 2019 assessment. We found that the skills related to early literacy and early numeracy competencies were relatively strong predictors of student achievement in mathematics, in agreement with previous studies (Duncan et al., 2007; Moll et al., 2015), including those studies which used TIMSS data from earlier cycles (Soto-Calvo & Sánchez-Barrioluengo, 2016; Radišić & Ševa, 2017).

Parents/guardians from the Dinaric region generally estimated their children as being able to do literacy and numeracy tasks “moderately well” on the TIMSS scale “Could do literacy and numeracy tasks when beginning primary school” (Mullis et al., 2020, exhibit 5.18), although the average on this scale for the Dinaric region appeared to be a little higher than the EU average reported in TIMSS 2011 by Soto-Calvo and Sánchez-Barrioluengo’s (2016) study.<sup>2</sup> The average ENT and ELT values

<sup>2</sup> For the participating education systems from the Dinaric region, the ELT average was 10.3 and the ENT average was 10.2 in TIMSS 2019. Calvo and Sánchez-Barrioluengo (2016) calculated an ELT average of 9.73 and an ENT average of 9.74 for EU education systems from the TIMSS 2015 data.



for Croatia were similar in TIMSS 2019 to their previously reported results from TIMSS 2011, whereas, between TIMSS 2015 and TIMSS 2019, average ENT and ET values decreased in Serbia.<sup>3</sup>

However, the majority of parents/guardians reported that their children could recognize letters from alphabet systems used in the Dinaric region (Latin and Cyrillic letters), and write their own name. The most likely explanation for those results is that these activities are recognized as representative for school readiness, since they are part of assessment at the school entrance. Although writing your own name is one of the developmental milestones in the emergent writing system (Puranik & Lonigan, 2011), it is interesting that recent findings are not conclusive on whether this skill, represented by knowledge concerning letter names, letter sounds, or more complex alphabetic principles (Drouin & Harmon, 2009; Molfese et al., 2011), is to be considered a good indicator of children's conceptual literacy knowledge.

When it comes to the numeracy competencies, our findings contribute toward understanding of the relation between early numeracy skills and different content domains of mathematics at school level, such as functional numeracy, geometry, data, or measurement. Early numeracy ability has been linked to later numeracy ability up to the age of adolescence in several studies (Geary et al., 2013). Our results extend this further by relating early numeracy with the domains of geometry and measurement, and data. Results from a previous study on longitudinal predictors of mathematics performance (LeFevre et al., 2010) found that early numeracy skills were related to numeration and calculation skills, but did not find any relationship to geometry and measurement skills later in schooling. This apparent variation in findings may be attributed to the different tasks used to measure geometry and measurement competencies. For example, TIMSS tasks related to geometry content domains involve measurement as well as numerical knowledge and skills (for example, students may be asked to calculate the perimeter of a rectangle). However, the tasks used in LeFevre et al. (2010) may have included a greater proportion of vocabulary items related to geometry, language-mediated processing on spatial arrays, and sequencing and patterning questions. Our findings were also broadly in agreement with numerous previous studies about the contribution of home resources for learning toward student achievement in mathematics (Cankaya & LeFevre, 2016).

Interestingly, we found that the association between preschool attendance and mathematical achievement was not significant, although some previous research has suggested otherwise (Yoshikawa et al., 2016). This is perhaps because preschool education may not have a long-term effect (Magnuson et al., 2007), but it may also be possible that the positive effect of preschool education is more pronounced for children from diverse and at-risk families who attend high-quality preschool programs (Thronsen et al., 2020). We did not consider these aspects of preschool education in our analyses. As to gender effects, our results are consistent with a large meta-analysis by Lindberg et al. (2010), which showed that there were no gender differences in mathematics performance (and that male and female variances

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<sup>3</sup> In Serbia, the average ELT value was 10.6 and average ENT was value was 10.3 for TIMSS 2015. In TIMSS 2019, these values had decreased to an ELT value of 10.0 and an ENT value of 10.0.

were closely equivalent). Given that our data was based on information collected from parents/guardians, we cannot dismiss the possibility that perceptions about the mathematical capacities and performance of some participants from the Dinaric region may be colored by their caregivers' beliefs and prejudices, and by established social gender stereotypes in the region (Steele, 1997, 2003).

Finally, our analyses showed distinct variance among the different parental groups in their overall reports on children's early literacy and numeracy competencies. This may be attributed to the effect of age differences in sampling the Dinaric region; in some of the education systems, preschool refers to children of age four to five, while, in other systems, this could refer to children of age five to six. Observed dissimilarities could result from the different levels of understanding among parents/guardians about what constitutes early literacy and numeracy competencies and what is age appropriate. This lack of knowledge about developmental trajectories is recognized as one of the main factors related to parental misrepresentation and overestimation of children's capabilities (Zippert & Ramani, 2017).

The limitations of this study are mainly related to the nature of the variables used in TIMSS and more generally in large-assessment studies, where the data on the relation between early cognitive competencies and later school achievement are captured only at a superficial level using few questions. In addition, when collecting information from parents/guardians about their children's development of mathematical competencies, parents/guardians are not always certain about placing their children's mathematical competencies in a comparative framework, especially when it comes to advanced number skills. They tend to overestimate their child's abilities for different number tasks, including the concept of cardinality, counting skills, and symbolic and non-symbolic arithmetic (Fluck et al., 2005; Zippert & Ramani, 2017). In TIMSS, the data on early cognitive skills of students are gathered from retrospective parental reports (TIMSS & PIRLS International Study Center, 2018), a fact that should be accommodated when considering parental estimations of their children's EL and EN skills.

The findings of our study suggest a range of possible avenues for researchers from the Dinaric region to investigate and explore in more depth, including further analysis of not only the early numeracy variables recognized in the literature as meaningful predictors of mathematics achievement (e.g., symbolic versus non-symbolic mathematical competencies) but also the measures that might provide a deeper understanding of parental attitudes and practices. The findings provide a good basis for the creation and improvement of numeracy development programs for parents/guardians, and provide robust data for policymakers about the impact of early childhood mathematics in current preschool curricula (Clements & Sarama, 2008; Thiel & Perry, 2018).

The results imply that parental estimates regarding the development of mathematical competencies before entering school are culturally conditioned. Traditionally, parents/guardians in the Dinaric region believe that children are supposed to know how to write and read words as well as perform simple addition before entering first grade. Results from TIMSS 2019 show that, in Dinaric region, parents/guardians still have relatively high expectations when it comes to their children's early numeracy

skills. However, small differences across the region are noticeable, possibly due to a shift in parental beliefs, attitudes, and practices related to this topic. Future TIMSS cycles will enable researchers and policymakers to identify potential changes and to develop appropriate programs for parents/guardians, helping them to facilitate numeracy development in their children in more effective and age-appropriate ways.

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