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The Influence of Early Literacy Competences on Later Mathematical Attainment

Evidence from TIMSS & PIRLS 2011

Elena Soto-Calvo

Mabel Sánchez-Barrioluengo

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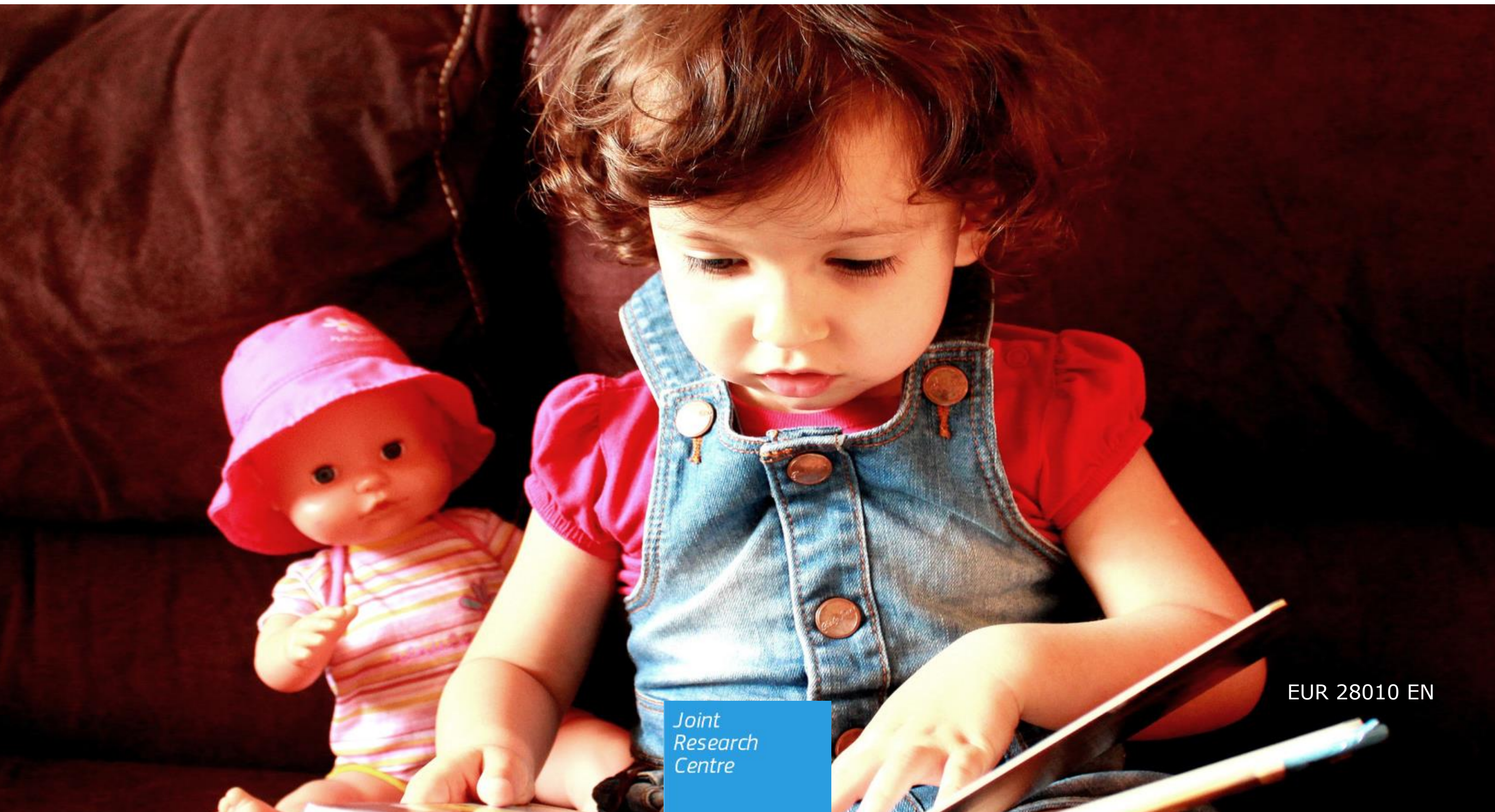

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Contact information
Name: Elena Soto-Calvo
Address: Liverpool John Moores University. Natural Sciences and Psychology, Byrom Street, Liverpool L3 3AF (United Kingdom)
E-mail: E.SotoCalvo@ljmu.ac.uk
Tel.: +44 151 904 6338

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Abstract

Children's competence levels in numeracy and literacy before or at school onset are good predictors of their attainment over the school years. Nevertheless, there are large differences in the level of numeracy and literacy knowledge among children at school entry. This initial knowledge gap has long-lasting negative consequences for the poor performers. Here we used international secondary data from the PIRLS&TIMSS 2011 as well as TIMSS 2011, including background data collected with the Learning to Read Survey, to identify early literacy practices that predict later mathematical attainment. Previous studies conducted using the same dataset have reported that early numeracy and literacy abilities before school onset (as reported by parents) are associated with students' later mathematical and reading attainment, respectively. Nevertheless recent theoretical frameworks of early mathematical development include certain literacy skills as an independent predictors of mathematical performance. Using ordinary least square regression models we found that early numeracy competences consistently predicted later mathematical attainment while the effects of early literacy competences were variable and not always significant for the individual countries. Results also showed a stronger influence of early reading abilities than of early writing abilities on later mathematical attainment. The identified effects were independent of children's gender, home resources for learning, parents' highest education and occupation level, student years of pre-school attendance and early numeracy abilities. This report complements and extents previous body of research by determining the relative impact that early literacy skills have on later mathematical attainment across EU countries. Findings highlight the importance of including numeracy and literacy practices in the preprimary curriculum as well as the challenges of implementing ECEC curricula on the basis of identified best practices from international research.

1 Introduction

Early Childhood Education and Care (ECEC) is defined as any regulated arrangement that provides education and care for children from birth to compulsory primary school age - regardless of the setting, funding, opening hours or programme content - and includes centre and family day-care; privately and publicly funded provision; pre-school and pre-primary provision (European Commission, 2014). The provision of high-quality ECEC has clear educational, social and economic advantages. It has not only been associated with better school adaptation but research also shows it is negatively associated with early school leaving (European Commission, 2014). The need for raising the quality of ECEC and for a more coherent educational policy for lifelong learning from early childhood has been stressed in several EU policy documents, as well as the urge to raise students' levels of knowledge in mathematics.

The ECEC curriculum has been identified in recent theoretical frameworks as a quality lever within the ECEC system (OECD Starting Strong Analytical Framework and the Key Principles of a Quality Framework for Early Childhood Education and Care Framework from the ECEC Thematic working group of the European Commission, 2014). It refers to the contents and methods that substantiate children's learning and development, including pedagogical practices (OECD, 2012).The present work examines the relative impact that early numeracy and literacy competences before the school onset have on students' later mathematical school attainment at fourth grade. It uses international secondary data from the PIRLS&TIMSS 2011 as well as TIMSS 2011, including aspects of the child and family background collected with the complementary Learning to Read Survey. Studies conducted using the same set of data have reported that children's early numeracy abilities before school onset as reported by parents are associated with their later mathematical school performance at 4th grade (Mullis et al., 2012) and that children's early literacy abilities before school onset a as reported by parents are associated with their later reading school performance at 4th grade (Mullis et al., 2012). Nevertheless, recent theoretical models of early mathematical development include verbal skills as an independent predictor of mathematical performance (Krajewski & Schneider, 2009; LeFevre et al., 2010). Thus this report provides a more complete and comprehensive picture of the importance that diverse types of early pedagogical competences before attending school have on later overall mathematical attainment as well as on distinct aspects of mathematics.

Alongside the importance of other skills that are general precursors of school readiness (e.g. self-regulation, self-control, delay of gratification, attention regulation, fine motor skills, motivation, locus of control), it is important to identify how early competences influence later school performance in order to identify effective pedagogical practices. This is essential in order to improve ECEC curricula and inform parents on how to provide the best home learning environment for their children.

2 Early predictors of mathematical competence

2.1 Introduction

The level of numeracy and literacy knowledge a child possesses when he or she starts school is a good indicator of how well this child will perform in the following school years. This suggests that the period from birth to the start of school is an important developmental phase where children acquire fundamental knowledge that will serve them as a base for later learning and school success. Nevertheless, there are large individual differences among children in their literacy and numeracy abilities at school entry, suggesting that some children are not provided enough and meaningful opportunities to acquire this fundamental knowledge from very early on. When young children lack an environment that enhances their capacities to learn, they are at potential risk of not adapting well to the school environment and this may have negative and long-lasting consequences to their school success (Aunola et al., 2004; Jordan et al., 2007). In this chapter we review the different competences and practices, background characteristics and cognitive skills that have been associated to early mathematical development.

2.2 Early competences and practices that influence mathematics development

ECEC and the home learning environment provide the space for children to learn and practice literacy and numeracy content. Preschool attendance has been associated with better academic performance later on (Anders et al., 2012; Belsky et al., 2007; Gorey, 2001; Magargee & Beauford, 2016; Peisner-Feinberg et al., 2001; Sella et al., 2016; Sylva et al., 2003; Vandell et al., 2010). Similarly, research shows that the learning environment can predict how well children do later in school; having access to a large number of books or other educational resources, doing family visits to the library and having quality interactions parent-child seem to enhance early child learning (Anders et al., 2013; Melhuish et al., 2008; Snow & Van Hemel, 2008; Son & Morrison, 2010; Totsika & Silva, 2004).

Nevertheless not all early activities taking place in the home environment have a significant impact in the child school readiness (see Melhuish et al., 2008) and recent body of research suggests that it is not just attendance but receiving high-quality ECEC that makes a positive difference to children's learning (Anders et al., 2012; Belsky et al., 2007; Gorey, 2001; Peisner-Feinberg et al., 2001; Vandell et al., 2010).

2.2.1 Early number competences that predict later mathematics performance

Early number competences are basic numerical abilities that children develop early in life though formal or informal contact with the formal number system. These include a wide range of numerical skills such as number sequence reciting, cardinal counting, understanding numerical relations, symbolic and non-symbolic number processing, performing basic arithmetic, etc. (see Aunio & Räsänen, 2015 for a review). There is a large body of evidence associating children's early number competences before school onset with their later mathematical performance over the school years (Aubrey & Godfrey, 2003; Aubrey et al., 2006; Aunio & Niemivirta, 2010; Aunola et al., 2004; Byrnes & Wasik, 2009; Duncan et al., 2007; Jordan et al., 2008; Jordan et al., 2007; Jordan et al., 2009; Krajewski & Schneider, 2009a,b; Pianta & LaParo, 2000; LeFevre et al., 2010; Lepola et al., 2005; Moll et al., 2015; Östergren & Träff, 2013; Passolunghi & Lanfranchi, 2012; Purpura et al., 2011; Romano et al., 2010; Soto-Calvo et al., 2016; Stock et al., 2009a,b; Tobia et al., 2015).

Practicing number activities within the preschool classroom context has been linked to better numeracy skills competence (Ramani et al., 2012; Starkey et al., 2004) as well as parents' reports on how frequently the child practices numeracy tasks at home (LeFevre et al., 2002; LeFevre et al., 2009; LeFevre et al., 2010; Figueredo et al., 2001; Kleemans et al., 2012; Young-Loveridge, 2004; Ramani & Siegler, 2008; Siegler & Ramani, 2008; Skwarchuk et al., 2014, but see also Blevins-Knabe et al., 2000; Huntsinger et al., 2000).

This evidence indicates that children's opportunities to learn numeracy content and practice numeracy activities in the very early years set the foundations towards their later mathematical competence over the school years.

2.2.2 Early literacy competences that predict later mathematics' performance

Early literacy skills refer to children's early oral and phonological processing skills as well as letter print knowledge (Purpura et al., 2011):

- Oral skills: These are aspects of language knowledge such as vocabulary, word knowledge and grasping the grammar rules of a language (Storch & Whitehurst, 2002).
- Phonological processing skills: These abilities enable the child to represent, encode and manipulate aspects of the phonological structure of the language. They include phonological awareness, phonological memory and rate of access to phonological codes (Hecht et al., 2001; Snowling, 2000).
- Print letter knowledge: This refers to the child ability to map letter names with their sound and to identify the direction of printed language (Whitehurst & Lonigan, 1998).

Early literacy skills have been found to play a crucial role in reading development (De Jong, 2007; Duff et al., 2015; Hulme et al., 2005; Gathercole et al., 2005; Hecht et al., 2001; Melby-Lervåg et al., 2012; Lonigan et al., 2000). Parental reports on the child literacy skills competences before the start of the school have also been associated with children's later reading abilities (Evans et al., 2000; Evans & Shaw, 2008; Leseman et al., 2007; Neuman et al., 2000; Reynolds et al., 2011; Sénéchal, 2006; Sénéchal & LeFevre, 2002; Skwarchuk et al., 2014).

Nevertheless, some early literacy skills are also important for mathematical development (Aiken, 1972). Several studies have provided empirical evidence supporting the association between children's vocabulary and phonological processing skills in early school years with their performance on standardised tests of mathematical attainment in later school years (Hecht et al., 2001; Moll et al., 2015; Simmons et al., 2008). Moreover, early literacy skills have been proposed to be particularly important for certain aspects of mathematics that rely heavily on phonological processing abilities such as numerical rote citing (Krajewski & Schneider, 2009a,b; Koponen et al., 2013) or performing basic arithmetic problems (De Smedt et al., 2010; Simmons & Singleton, 2008, 2009; Soto-Calvo et al., 2015). There is also limited body of research associating early literacy practices in the home environment with later mathematical performance (Moll et al., 2015; Purpura et al., 2011, LeFevre et al., 2010).

In the present work, students' early numeracy and literacy competences before they began school (as reported by their parents) constitute our independent variables. Based on the findings included in this section we expect that both, early numeracy and early literacy competences before students started school to be positively related to their mathematical performance in school.

2.3 Child characteristics and environmental factors that influence early mathematical development

Child and family background characteristics may also affect children's possibilities to learn. Studies on early school success have associated certain background characteristics such as gender, socio-economic status (SES), parents' educational characteristics, household income and the amount of time and the quality of the ECEC settings with early mathematical development.

2.3.1 Gender

From the very early years children's gender shapes their preferences in learning activities, particularly those chosen during free play time. Studies conducted with very young children suggest that while boys tend to engage in play activities that draw heavily on gross motor skills, girls opt for activities that require more fine-motor skills and that are more verbally mediated (Early et al., 2010; Ruble et al., 2006; Tonyan & Howes, 2003). These differences in interests and activities have been proposed to impact the extent to which very young children develop distinct early skills for future learning, including their early numeracy development (Anders et al., 2013).

2.3.2 Socio-economic status (SES)

The association between SES and early learning is well-documented, whether for general learning outcomes (e.g. Larson et al., 2015; OECD, 2013) or specifically for early numeracy (e.g. Anders et al., 2013; Jordan & Levine, 2009). Having parents with higher educational levels (Anders et al., 2013; Burchinal et al., 2002; Sammons et al., 2004) or growing up in a home with higher household income (Bradley et al., 2001; Melhuish et al., 2008) have been positively linked to children's early literacy and numeracy competences.

2.3.3 Parenting characteristics

Parents' behaviours, expectations and attitudes towards their children are also important for their offspring's learning from very early on. Children need to be surrounded by adults who stimulate their learning and provide them with affective support. Many aspects of parenting quality have been associated with children's early learning processes. For instance, children whose parents are sensible and provide appropriate cognitive stimulation tend to do better at school (Adi-Japha & Klein, 2009; Belsky et al., 2007; Burchinal et al., 2002; Englund et al., 2004; LeFevre et al., 2002), including in the mathematic domain (Jacobs et al., 2005; LeFevre et al., 2009). Similarly, the frequency of affective mother-child interactions has been found to enhance the child learning outcomes over the early years (Bradley, 2002). Parental positive attitudes and expectations of children's learning have also been found to be good predictors of school attainment (Englund et al., 2008; Martini & Sénéchal, 2012; Skwarchuk, 2009; Soni & Kumari, 2015) and also of numerical competences (Blevins-Knabe et al., 2007; Skwarchuk et al., 2014).

2.3.4 ECEC attendance and quality

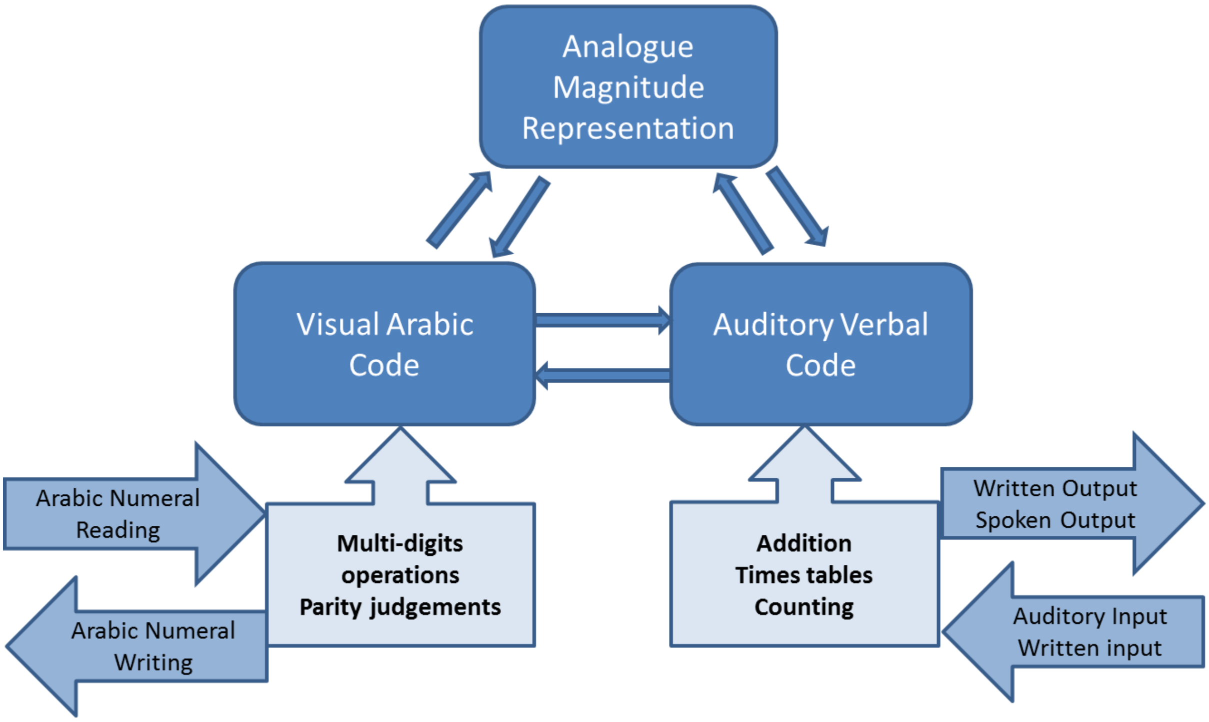
The importance of attending pre-school education in preparing children for their future learning is well documented (Barnett, 2001; Belsky et al., 2007; Magnuson et al., 2004; NICHD ECCRN, 2003, 2005; OECD, 2013; Peisner-Feinberg et al., 2001; Sylva et al., 2003; Rossbach et al., 2008). Characteristics of the ECEC environment such as the center's composition have been associated to the child later competences (Melhuish et al., 2008). Research also shows that the time spent in ECEC settings is a good predictor of the child early numeracy competences (Anders et al., 2013).

In this report we take into consideration these influencing factors and control for their effects when determining the influence of early literacy and numeracy practices on later mathematical school attainment. Students' gender and several background characteristics (i.e. sex of the student, home resources for learning, student attendance to pre-school and parents' highest education and highest occupation level) are included in the statistical models so that results cannot be confounded with these child and environmental aspects.

2.4 Theoretical models of early mathematical development

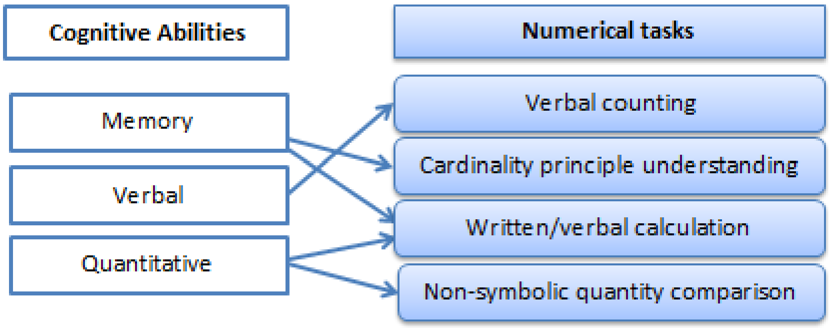
Recent theoretical models of early mathematical development postulate that different cognitive skills are independent predictors of preschoolers' mathematical development over the early school years (Krajewski & Schneider, 2009a; LeFevre et al., 2010). These models were developed from Dehaene's and colleagues' seminal work (Dehaene et al., 2003; Dehaene et al., 1999) on the cognitive predictors of mathematical performance in adults. Dehaene's model is based on converging evidence from behavioural, neuropsychological and neuroimaging studies conducted with adults. It proposes a modular structure of the way numerical information is processed; while all numerical tasks involve the processing of abstract numerical representations, visual-spatial or verbal representations may also be processed depending on the nature of the number task. More precisely, verbal abilities needed for tasks such as reciting times tables and exact arithmetic because these require number fact retrieval in the form of phonological codes (De Smedt et al., 2010) whilst visual-spatial representations would be needed in tasks such as number comparison (Dehaene et al., 2003). This model also proposes that the extent to which verbal, visual-spatial and quantitative presentations are involved numerical tasks depends on the format presentation of the task (See Figure 1).

Figure 1. Dehaene's (1992) diagram of the triple-code model of number processing



LeFevre et al.'s (2010) and Krajewski and Schneider's (2009b) models are based on longitudinal studies conducted with preschoolers and propose that memory skills, verbal skills and quantitative skills support the development of distinct numerical skills in very young children. As well as in Dehaene and colleagues' (1999, 2003) proposal, a key common aspect of these two models is that the extent to which verbal, visual-spatial and quantitative presentations are involved in early numerical processing depends on the format presentation and cognitive demands of the numerical task. For instance, quantitative skill would be used when performing numerical comparisons (Dehaene et al., 2003) and abstract arithmetic calculations (LeFevre et al., 2010), visual-spatial representations would be needed in tasks such as cardinal counting (Ansari et al., 2003) and verbal skills would be needed for tasks such as number rote citing (Koponen et al., 2013) and reciting times tables (Simmons & Singleton, 2009) because these numeracy skills make heavy demands on verbal processes (see Figure 2).

Figure 2. Identified Relationships between Cognitive Abilities and Early Numeracy Tasks



Note. Evidence from Krajewski and Schneider (2009b) and LeFevre et al. (2010)

In this report we examine the effects that children's early numeracy and early literacy competences before the start of school (as reported by parents) have on their overall mathematics attainment but also on different aspects of mathematics using the sub-scales scores. We expect that early literacy knowledge will impact overall mathematical performance. Greater effects of literacy skills are expected for mathematical content domains that draw more heavily on verbal skills.

3 ECEC and numeracy competences in the EU policy

3.1 Introduction

In this chapter we review several EU policy documents that have set up objectives or initiatives in education. We include in separate sections first those targeting quantity objectives and then those targeting quality objectives. We also include a section reviewing the policy documents that make a special emphasis on the importance of raising the level of numeracy skills in EU and the current ET2020 objectives. Last, we review two recent ECEC quality frameworks (i.e. OECD Starting Strong Analytical Framework and the Key Principles of a Quality Framework for Early Childhood Education and Care Framework from the ECEC Thematic working group of the European Commission, 2014) where the ECEC curricula have been identified as a key ECEC quality lever.

3.2 ECEC and EU policy

3.2.1 ECEC quantity objectives in EU policy

Policies targeting ECEC quantity objectives have been in place for over two decades. Widening access to ECEC has been mainly regarded as a mean to achieve EU social and economic objectives including preventing child poverty and social exclusion, supporting the successful integration of females and immigrants in the labour market, and providing equal opportunities to children from disadvantaged backgrounds and other minorities. Some of the key documents and conclusions that considered ECEC access over the last two decades are the following:

- **The Barcelona summit (2002)**[1]: The Commission adopted two targets in relation to access to ECEC:
  - To provide childcare to at least 90% of children between 3 years old and the mandatory school age
  - To provide childcare to at least 33% of children under 3 years of age
- **The Presidency Conclusions on the re-launched Lisbon Strategy for jobs and growth from the Council of the European Union (2006) (7775/1/06)**[2], where increasing availability of quality childcare is regarded as a mean to promote women's employment and to ensure a better work-life balance.
- **The staff working document on the implementation of the Barcelona objectives concerning childcare facilities for pre-school-age children from the European Commission (2008) (SEC(2008) 2524),** where childcare facilities for pre-school-age children are considered beneficial towards reaching gender equality in employment opportunities.
- **The Council Conclusions on the education of children with a migrant background (2009)**[3], in which the MS were invited to "Take appropriate measures at their required level of responsibility — local, regional or national with a view to ensuring that all children are offered fair and equal opportunities, as well as the necessary support to develop their full potential, irrespective of background" and suggested increasing access to high-quality ECEC as a key measure towards that particular aim.

[1] http://ec.europa.eu/invest-in-research/pdf/download_en/barcelona_european_council.pdf
[2] http://www.consilium.europa.eu/ueDocs/cms_Data/docs/pressData/en/ec/89013.pdf
[3] http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52009XG1211%2801%29&from=EN

- **The Conclusions on the social dimension of education and training from the Council of the European Union (2010) (2010/C 135/02)**[4], in which MS were invited to "Ensure wider access to high-quality ECEC, in order to give all children - particularly those from disadvantaged backgrounds or with special education needs - a sure start, as well as to increase the motivation to learn." (p. 6, Council of the European Union, 2010).

3.2.2 ECEC quality objectives in EU policy

Unlike ECEC quantity, emphasis on improving and monitoring ECEC quality has only been introduced in the EU policy agenda in the recent years. Nevertheless it is now one of the EC main objectives. Making ECEC more accessible and of high quality is regarded as a strategy to increase children's cognitive and basic skills and to secure a competent foundation of high quality lifelong learning education. Throughout these documents, parental engagement, high-qualified ECEC staff and a competent curriculum are identified as important elements for high quality ECEC provision. Some of the key communications, reports and resolutions that considered not only ECEC quantity targets but also stress the need to ensure ECEC quality for later learning are the following:

- **The joint interim report on the Education and Training 2010 work programme from the Council and the Commission (2006) (5394/10)**[5], in which investing in pre-primary education was considered a priority towards preventing school failure and social exclusion, as well as for laying the foundations for further learning.
- **The communication on the efficiency and equity in European education and training systems from the European Commission (2006) (COM(2006) 481)**[6] where they call for attention to the quality of ECEC provision: "The type of early childhood provision and the pedagogy to be used should be considered carefully. Programmes focusing on learning as well as personal and social competences tend to produce better outcomes and, consequently, greater knock-on effects throughout life." (p. 5, European Commission, 2006) and suggested that parent engagement and specially trained pre-primary teachers are necessary to achieve high quality standards in ECEC.
- **The resolution on efficiency and equity in European education and training systems from the European Parliament (2007) (2007/2113(INI)**[7], where with regards to ensuring efficiency and equity in pre-school education make the following statements:

➢ Believes that efficiency and equity can be achieved on an individual basis if investment and reform are focused on the early stages of education;
➢ Stresses the need to develop, from the pre-school phase, measures to encourage the integration of children from third countries resident in the territory of the European Union;
➢ Calls upon the MS to invest much more in pre-school - including nursery - education, since such investment can be an effective means of establishing a basis for future education, for developing a child's intellect and for raising overall skills levels, and can significantly increase the equity of the education system;
➢ Believes however that more research into pre-school education is necessary at EU level, in particular in the field of early and targeted actions, in order to identify practices which produce the expected effects;
➢ Considers the quality of pre-school education to be partly dependent on adequately trained teachers, and that there is therefore a need for a financially

[4] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:C:2010:135:0002:0007:EN:PDF
[5] http://register.consilium.europa.eu/doc/srv?l=EN&f=ST%205394%202010%20INIT
[6] http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52006DC0481&from=EN
[7] http://www.europarl.europa.eu/sides/getDoc.do?Type=TA&Reference=P6-TA-2007-0417&language=EN

viable strategy which will result in both future-oriented and high quality education and satisfactory teaching careers;

- Acknowledges that as from the pre-school stage, social diversity of classes and establishments must be ensured in order to avoid a differentiation of curricula and expectations;
- Believes the involvement of parents by means of educational and information programmes (particularly in the case of disadvantaged children) to be important to the success of pre-school education;
- Is in favour of all forms of pre-school education and intervention at an early age (when children's cognitive skills are developing) - this being of all the stages in the entire process of life-long learning the one which pays the highest dividend;
- Urges MS to increase the number of subsidised places in pre-school education, thereby offering better opportunities to children under school age who lack financial security to benefit from the education system;

- **The communication on Early Childhood Education and Care: Providing all our children with the best start for the world of tomorrow from the Commission (2011) (COM(2011) 66)**[8] which highlights the social, economic and educational benefits of a having a universal, high-quality and inclusive ECEC system. Within this document, several actions are proposed to policy cooperation among MS. The ones included towards improving ECEC quality are:
  - Finding the appropriate balance in the curriculum between cognitive and non-cognitive elements
  - Promoting the professionalisation of ECEC staff: what qualifications are needed for which functions
  - Developing policies to attract, educate and retain suitably qualified staff to ECEC
  - Improving the gender balance of ECEC staff
  - Moving towards ECEC systems which integrate care and education, and improve quality, equity and system efficiency
  - Facilitating the transition of young children between family and education/care, and between levels of education
  - Quality assurance: designing coherent, well-coordinated pedagogical frameworks, involving key stakeholders
- **The Communication on Rethinking Education: Investing in skills for better socio-economic outcomes from the European Commission (2012) (COM(2012) 669)**[9] where the Commission identifies that Building Transversal and basic skills for the 21st century as one of the challenges to be addressed by the MS and suggest that in order to ensure that all citizens acquire key foundation or basic skills "compulsory schooling needs to be preceded by high-quality, accessible and affordable ECEC. They should be complemented with family literacy and numeracy programmes as well as high quality adult basic skills programmes, particularly through workplace learning" (p. 5, European Commission, 2012).
- **The drafted Joint Report on the implementation of Relevant and high-quality skills and competences, focusing on learning outcomes, for employability, innovation and active citizenship of the Council and the Commission (2015) (COM(2015) 408)**[10] in which the European Commission calls for policy coherence from early childhood education and lists raising the quality of Early Childhood Education and Care (ECEC) as one of the main challenges and future priorities for the EU policy agenda.

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[8] http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52011DC0066&from=EN
[9] http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52012DC0669&from=EN
[10] http://ec.europa.eu/education/documents/et-2020-draft-joint-report-408-2015_en.pdf

3.2.3 Impact of mathematic knowledge and urge to improve numeracy skills in Europe

With regards numeracy competences, several EU policy documents have highlighted the importance of raising students' levels of numeracy skills and knowledge in mathematics. Compulsory mathematics teaching has been considered an important requirement to ensure students' participation in society.

- **The European Report on the Sixteen Quality Indicators from the Working Committee on Quality Indicators (2000)**[11], where mathematics are consider a way to acquire analytical skills, logic skills and numerical reasoning skills and identified as one of the indicators for quality of school education. And adds that "The principal challenges in relation to mathematics are to develop a teaching method which ensures that pupils have a positive attitude towards mathematics, encourage pupils to develop and maintain their knowledge in this area, and define, if possible, the common skills and competences which European citizens should possess."
- **The report on the concrete future objectives of education and training systems from the European Commission (2001) (COM(2001) 59)**[12] that emphasised the need to develop skills in the society, among which, they make a special consideration to increasing citizens' level of knowledge in literacy and numeracy; "Ensuring that all citizens achieve an operational level of literacy and numeracy is an essential precondition to quality learning. These are the key to all subsequent learning capabilities, as well as to employability […] In a society which enables people to absorb more and more without reading, other means have to be found to persuade them that developing and maintaining literacy and numeracy skills at effective levels is essential both personally and professionally." (p. 8, European Commission, 2001). And adds that "Europe needs an adequate throughput of mathematics and scientific specialists in order to maintain its competitiveness. In many countries interest in mathematics and science studies is falling or not developing as fast as it should. This can be seen at school, where the uptake of these subjects by pupils is lower than could be expected; in the attitude of young people and parents to these subjects and later in the level of new recruitment to research and related professions. There is also a problem of recruiting women to these fields as well as the serious problem of keeping highly skilled researchers inside the borders of the EU. The present situation is already a cause for concern to employers; but further work would be required to analyse the full range of reasons why many of those qualified to do research in these fields do not find them sufficiently attractive, and choose to take up quite unrelated professions […] The citizen need to have a basic understanding of mathematics and science if they are to understand the issues, and make informed - even if not technical – choices" (p. 10, European Commission, 2001).
- **The Recommendation on key competences for lifelong learning from the European Parliament and the Council (2006) (2006/962/EC)**[13], where mathematical competence and basic competences in science and technology was again considered one of the key eight competences for personal fulfilment and development, active citizenship, social inclusion and employment.
- **The Conclusions on preparing young people for the 21st century: an agenda for European cooperation on schools from the Council (2008)**[14], where the MS were invited to focus cooperation on, among other issues, "stimulating greater interest in mathematics, science and technology, in order to

[11] http://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=URISERV:c11063&from=EN
[12] http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52001DC0059&from=EN
[13] http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32006H0962&from=EN
[14] http://www.consilium.europa.eu/uedocs/cms_Data/docs/pressdata/en/educ/104238.pdf

develop scientific ways of thinking from an early age" (p. 5, Council of the European Union, 2008).

- **Council Conclusions on a strategic framework for European cooperation in Education and Training ('ET 2020')[15],** in relation to the strategic objective of improving the quality and efficiency of education and training, it is stated that "the major challenge is to ensure the acquisition of key competences by everyone, while developing the excellence and attractiveness at all levels of education and training that will allow Europe to retain a strong global role. To achieve this on a sustainable basis, greater attention needs to be paid to raising the level of basic skills such as literacy and numeracy, making mathematics, science and technology more attractive and to strengthening linguistic competences" (p. 3, Council of the European Union, 2009) and adds that "High quality (assurance systems) will only be achieved through the efficient and sustainable use of resources — both public and private, as appropriate — and through the promotion of evidence-based policy and practice in education and training." (p. 4, Council of the European Union, 2009).
- **The drafted Joint Report on the implementation of Relevant and high-quality skills and competences, focusing on learning outcomes, for employability, innovation and active citizenship of the Council and the Commission (2015) (COM(2015) 408)[16]**, where the MS are encouraged to implement targeted policy action to reduce low achievement in basic competences across Europe, covering literacy, mathematics, science and digital literacy (European Commission, 2015) which is under the priority of raising the relevant and high-quality skills and competences of citizens, focusing on learning outcomes, for employability, innovation and active citizenship.

3.2.4 Current ET2020 benchmarks in relation to ECEC and numerical competence

In 2009, the Council of the European Union proposed the strategic framework for European cooperation in education and training ('ET 2020') (2009/C 119/02)[17] and agreed that "lifelong learning should be regarded as a fundamental principle underpinning the entire framework, which is designed to cover learning in all contexts — whether formal, non-formal or informal — and at all levels: from early childhood education and schools through to higher education, vocational education and training and adult learning." (p. 3, Council of the European Union, 2009). Within this document, four strategic objectives were outlined:

- Making lifelong learning and mobility a reality;
- Improving the quality and efficiency of education and training;
- Promoting equity, social cohesion and active citizenship;
- Enhancing creativity and innovation, including entrepreneurship, at all levels of education and training.

In particular, in objective 3 it was stated that "Educational disadvantage should be addressed by providing high quality early childhood education and targeted support, and by promoting inclusive education." (p. 4, Council of the European Union, 2009).

Moreover, two additional ET2020 benchmarks are also strongly related to the aims of this project. The low achievers in basic skills benchmark proposes that:

- "By 2020, the share of low-achieving 15-years olds in reading, mathematics and science should be less than 15 %"

[15] http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:52009XG0528(01)
[16] http://ec.europa.eu/education/documents/et-2020-draft-joint-report-408-2015_en.pdf
[17] http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52009XG0528%2801%29&from=EN

And the early leavers from education and training, which proposes that:

- "By 2020, the share of early leavers from education and training should be less than 10%".

These two benchmarks aim at ensuring that all learners attain an adequate level of basic skills, especially in reading, mathematics and science and that a maximum number of learners complete their education and training, respectively. Both are linked to the current study aims because this report aims to inform on ways to improve mathematics curricula and because high-quality of ECEC has been negatively associated to early school leaving (European Commission, 2014).

3.3 ECEC Quality Frameworks

Two recent ECEC quality frameworks (OECD Starting Strong Analytical Framework and the Key Principles of a Quality Framework for Early Childhood Education and Care Framework from the ECEC Thematic working group of the European Commission, 2014) have identified the ECEC curriculum as a key element to raise ECEC quality among other elements such as ECEC staff, the families and communities and the children.

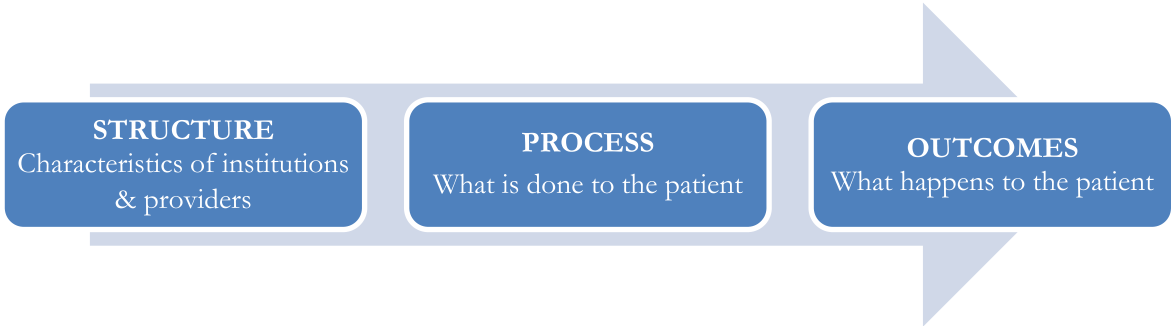
3.3.1 The Quality Framework for ECEC proposed by the European Commission working group on ECEC (2014)[18]

The Quality Framework for ECEC proposed by the European Commission working group on ECEC (2014) merges findings from Eurydice, OECD, the European Childcare Network and other organisations, as well as evidence from policy and practice in the MS and cross-national research findings. This framework is child-oriented, this is, the child is the key central element; an individual who has his/her own emotional, physical, social and cognitive needs and who takes active role in his/her learning process. Based on Donabedian's quality framework of components and outcomes of care (1988) (see Figure 3), this framework distinguishes three distinct measures of quality in ECEC:

- **Structural Quality:** Includes all the factors that affect the context in which education and care is delivered. It consists of "inputs to process-characteristics which create the framework for the processes that children experience" (p. 6, European Commission, 2014). These characteristics are not only part of ECEC provision but are also part of the environment that surrounds ECEC settings. The regulations, accreditations and requirements in relation of the components of the ECEC system are aspects of the ECEC structural quality as well as the design of the curriculum, organisation of finances, arrangements of health and safety, etc.
- **Process Quality:** This refers to the actual practices taking place within the ECEC setting. According to the ECEC framework it consists of what children actually experience in their programmes, including the relationships and interactions with other stakeholders (parents and ECEC staff) and the day-to-day pedagogical practices.
- **Outcome Quality:** This refers to the benefits that high-quality ECEC has for its stakeholders. In particular for the children these would be all aspects of their development. This refers to the child's school readiness but also to his/her social, emotional, moral, mental and physical wellbeing.

[18] See http://ec.europa.eu/education/policy/strategic-framework/archive/documents/ecec-quality-framework_en.pdf

Figure 3. Diagram of Donabedian's quality framework of components and outcomes of care



This framework for ECEC quality identifies five key transversal areas for quality provision of ECEC:

- **Access:** A family is considered to have 'access' to ECEC when a place is available or can be made available in a quality ECEC setting where neither distance nor cost presents a barrier to attendance. Accessibility refers to problems parents experience in gaining access to ECEC services. These can be caused by explicit or implicit barriers, such as parents' inadequate knowledge of procedures or the value of ECEC, physical barriers for children with disabilities, waiting lists, a lack of choice for parents, language barriers etc. Legal entitlement to ECEC is when every child has the enforceable right to benefit from ECEC provision.
- **Governance and funding:** Governance is the allocation of responsibility within and across levels of government and between public and non-public providers, and includes mechanisms to coordinate these responsibilities.
- **Workforce:** The workforce refers to all staff members working directly with children in any regulated arrangement that provides education and care for children from birth to primary school age. The workforce includes leaders and managers, and other professionals working in ECEC settings.
- **Curriculum:** A curriculum framework (which can be a national, regional or local arrangement) expresses a set of values, principles, guidelines or standards which guides the content of an approach to children's care and learning. The ECEC curriculum (which includes those aspects which are implicit rather than explicit) covers developmental care, formative interactions, children's learning experiences and supportive assessment. This is normally set out in formal documentation, which informs on the objectives of children's personal and social development, and their learning experiences.
- **Evaluation and monitoring:** ECEC Evaluation refers to the systematic assessment of the effectiveness of the design, implementation or results of an on-going or completed ECEC project, programme or policy. Monitoring ECEC refers to the continuous and systematic collection of quantitative and qualitative data which supports a regular review of the quality of the ECEC system. It is based on pre-agreed quality standards, benchmarks or indicators which are established and modified through use.

The areas are proposed to be independent factors that relate to ECEC quality but that are intertwined and influence one another (see Figure 4):

Figure 4. Diagram of the Key principles of Quality Framework for ECEC quality

3.3.2 The OECD Starting Strong analytical framework[19]

The Starting Strong studies I (2001), II (2006), III (2012) and IV (2015) provide comparative data on ECEC policy in OECD countries. These studies have highlighted the importance of ECEC for "better social and economic development for the society at large" (Starting Strong III, OECD, p. 9) but emphasise that these benefits depend heavily on the quality of ECEC and not just attendance. Five key levers for increasing ECEC quality are identified in the toolbox OECD starting strong framework (see Figure 5).

Figure 5. Diagram representing the five key levers for increasing ECEC quality identified by OECD (2012)

These five key levers are:

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[19] http://www.oecd.org/newsroom/earlychildhoodeducationandcare.htm

- **Setting out quality goals and regulations** – Quality-focused goals are important so that resources and stakeholders' work are used towards the same objectives. Transparent regulations and setting minimum standards help achieve these objectives by ensuring better conditions for all and by providing clear information to parents about the available ECEC choices.
- **Designing and implementing curriculum and standards** – These are particularly important to level the field across different ECEC settings. The content and approaches of the curricula vary across counties, nevertheless the curriculum in many OECD counties give priority to the literacy and numeracy learning domains. ECEC curricula allows parents to be informed of the activities taking place in the ECEC setting and what they can do at home to enhance their children development.
- **Improving qualifications, training and working conditions** – Staff with high and specific qualification is in a better place to provide adequate and meaningful interactions with the children. Working conditions and staff satisfaction may affect, among others, the quality of the pedagogic practices that take place in the ECEC setting.
- **Engaging families and communities** – The engagement of parents and their effective communication with the ECEC staff are of particular importance towards providing the children a high quality home learning environment.
- **Advancing data collection, research and monitoring** – ECEC quality can be raised through the use of data and monitoring. To this end, research evidence is essential to inform policy and practice.

3.4 ECEC curriculum as a quality level element in the ECEC system

Both of the frameworks presented above (section 3.3) view the ECEC as a complex system in which elements are strongly interlinked and cannot be considered in isolation. For instance, an improvement in ECEC pedagogical practices is unlikely to be effective if the ECEC workforce is not properly trained for their professional role or if there is a lack of efficient coordination within the ECEC governance. Both frameworks are strongly child driven, placing the interests of the child and his or her development and wellbeing as main priorities within the framework. Communication among the different elements is regarded as essential towards this aim. Most importantly both proposals emphasise the need of providing children the best opportunities for learning as well as ensuring their wellbeing, cognitive and socio-emotional development through learning standards, curriculum design and curriculum implementation. To this end, the curriculum must provide explicit and clear goals and consider different teaching and learning approaches, including general learning areas such as literacy and numeracy but also individual, local and current needs. This is to be achieved by including experimental learning, play and social interactions, among others, as part of the learning programme. It must be design with a life-long learning perspective as to enhance children's interests, needs and potentialities.

The present research informs about how the early pedagogical practices that take place before school onset (whether in the ECEC setting or in the home environment) can potentially enhance later school performance.

4 Methodology

4.1 Attainment Surveys

The Trends in International Mathematics and Sciences Study (TIMSS) and the Progress of International Reading Literacy Study (PIRLS) are conducted by the International Association for the Evaluation of Educational Achievement. This international cooperative provides international benchmarks that allow for the identification of strengths and weaknesses of education systems to assist policymakers. TIMSS and PIRLS are the largest international comparative studies in educational attainment. These two surveys are curriculum-based and gather cross-sectional data on school-aged children's attainment, providing comparable indicators across countries and across time points. TIMSS and PIRLS data are collected using a two-stage clustered random sample design. First, schools are selected and then one class in the selected school is randomly chosen for the study. Both surveys include sub-scales tapping specific aspects of mathematics and reading and provide an overall score as well as a score for each sub-scale included in the questionnaires. Although these two surveys are administered on different fixed-year cycles, both surveys were administered in 2011, providing a very rich database that allows for the examination of the relationships between distinct aspects of reading and mathematics. Annex I includes detailed information about the surveys used in this report.

4.2 Background Questionnaires

TIMSS and PIRLS include several background questionnaires (student, teacher, school and curriculum). In addition, PIRLS also includes a parent (or guardian) background questionnaire named "The Learning to Read Survey". These questionnaires gather valuable information on the students' contexts for learning.

4.2.1 Student Questionnaire

Students are administered the student background questionnaire together with the attainment questionnaire and are given 30-minute to complete it. This questionnaire gathers information regarding students' demographic information and their home learning environments, such as gender, age, how often does he/she use the language in which the questionnaire is presented at home, characteristics of their household, studying and free time routines, characteristics of their school and their attitudes towards it, and their habits and attitudes towards their school reading and mathematics lessons.

4.2.2 Teacher Questionnaire

Teachers are asked to complete a questionnaire asking about their demographic characteristics, educational background, teaching experience, behaviors and attitudes towards teaching, characteristics and beliefs about the school as a whole and of the class participating in the study, and teaching activities in this class. This questionnaire also includes items on resources available for teaching and learning, homework assignment and the attainment and progress within the class.

4.2.3 School Questionnaire

Principals of the participating schools are asked to complete a questionnaire about their school characteristics, teaching and learning routines, priorities and resources, involvement of parents in the students' learning process, the school's climate, evaluation methods used to assess teachers, attitudes and behaviours towards their role, and attainment and progress within the school.

4.2.4 Curriculum Questionnaire

The Country Research Coordinator is asked to complete a questionnaire on the organisation, content and priorities of the school curriculum, general and specific educational policy characteristics within the country and teachers requirements.

4.2.5 Home Questionnaire (Learning to Read Survey)

Parents or guardians of the students participating in the PIRLS' assessments are asked to complete "The Learning to Read Survey". This questionnaire asks about characteristics of the child home learning environment before and when he or she began school, such as language spoken in the home, how often did the respondent engage in early learning numeracy and literacy activities with the child and the child level of numeracy and literacy competences. It includes items regarding concurrent learning activities and attitudes of his/her child and on respondents' engagement with the child learning process, believes and attitudes towards his/her child learning activities and progress. Respondents are also asked about their own reading routines at home, their attitudes towards reading, the home resources for learning, their educational level and employment status. As described in the TIMSS and PIRLS' Assessment Framework and Instrument Development[20], most context questionnaire items were designed to be combined into scales measuring a single underlying latent construct. Different scales were built from this data[21]. For the present work, two of these scales will be used; the Early Literacy Task scale (ELT) and the Early Numeracy Task scale (ENT).

4.2.5.1 The Early Literacy Tasks Scale

The Early Literacy Tasks (ELT) scale consists of five items from The Learning to Read Survey in which the parent or guardian is asked about how well could his/her child do the following literacy tasks before he/she began primary school:

- Recognise most of the letters of the alphabet
- Read some words
- Read sentences
- Write letters of the alphabet
- Write some words

For each item, parents are asked to choose the response (very well; moderately well; not very well; not at all) that best describes how well their child could do an early literacy task when began primary school. The higher the score on this scale, the better the student performed early literacy tasks.

4.2.5.2 The Early Numeracy Tasks Scale

The Early Numeracy Tasks (ENT) scale consists of six items from The Learning to Read Survey in which the parent or guardian is asked whether his/her child could do six different numeracy tasks before he/she began primary school. Parents are asked to respond on a 4-point scale for the first four items and to give a yes/no answer for the last two items:

- Count by himself/herself (up to 100 or higher; up to 20; up to 10; not at all)
- Recognize different shapes (e.g. square, triangle, circle) (more than 4 shapes; 3-4 shapes; 1-2 shapes; none)
- Recognize the written numbers from 1-10 (all 10 numbers; 5-9 numbers; 1-4 numbers; none)
- Write the numbers from 1-10 (all 10 numbers; 5-9 numbers; 1-4 numbers; none)

[20] http://timssandpirls.bc.edu/methods/pdf/TP_Instrument_Devel.pdf
[21] Information about the different scales is available here: http://timssandpirls.bc.edu/methods/t-context-q-scales.html

- Do simple addition (yes/no)
- Do simple subtraction (yes/no)

The higher the score on this scale, the better the student performed early numeracy tasks.

4.3 The Combined International Database

TIMSS 2011 collected data from 4th and 8th grade students while PIRLS 2011 only collected data from 4th grade students. Fourth grade students were defined as those who have undergone four years of education in school counting from the first year of International Standard Classification of Education (ISCED) Level 1. Countries participating in TIMSS and PIRLS 2011 were given the option of using the same sample of students for both studies. Over 180,000 students, 170,000 parents, 14,000 teachers, and 6,000 school principals from 34 countries and 3 benchmarking entities participated in the combined TIMSS and PIRLS assessments in 2011 (see Table 1).

Table 1. Countries and jurisdictions participating in TIMSS and PIRLS 2011

EU countries/ jurisdictions	Austria; Croatia; Czech Republic; Finland; Germany; Hungary; Ireland; Italy; Lithuania; Malta; Poland; Portugal; Romania; Slovak Republic; Slovenia; Spain; Sweden
Non-EU countries	Australia; Azerbaijan; Botswana; Chinese Taipei; Georgia; Honduras; Hong Kong SAR; Iran; Japan; Kazakhstan; Republic of Korea; Morocco; Northern Ireland; Norway; Oman; Qatar; Russian Federation; Saudi Arabia; Singapore; United Arab Emirates
Benchmarking	Abu Dhabi (UAE); Dubai (UAE); Quebec (Canada)

The Combined International Database includes for all the aboved-listed countries information from:

- The student's questionnaire
- The teacher's questionnaire
- The principal's questionnaire
- The parent/guardian questionnaire (Learning to Read Survey)

Only data from the student and the parent questionnaires are considered for the current study.

4.3.1 Specific characteristics of the TIMSS and PIRLS 2011 Combined Database

TIMSS and PIRLS data collections use a two-stage stratified cluster sample design. First, the school is selected and then one intact class in that school participates in the study. A clear benefit of this sampling strategy is the avoidance of testing a disproportionate number of participants and the prevention of high attrition rates. The participating students are assigned subsets of the whole item pool which saves all respondents from having to answer all items in the survey as well as enormous time demands. Nevertheless, these sampling strategies automatically result in some error because estimate scores need to be used for the missing data[22]. To properly estimate sampling

[22] More information on TIMSS and PIRLS achievement scaling methodology is available at: http://timssandpirls.bc.edu/methods/pdf/TP11_Scaling_Methodology.pdf

variance, TIMSS and PIRLS apply Jackknife Repeated Replication, using sampling weights and variance estimation techniques which take into account the characteristics of the sample and selection procedure when adjusting for the missing responses. This statistical strategy deletes different sub-samples from the full sample to form a number of replicate samples and adjusting weights of the remaining units to account for the deleted ones. Because we are using data at student level, we applied the students' weights in all our analyses.

4.3.2 Databases for the empirical analysis

For the present report we use two sources of data: TIMSS and PIRLS 2011 International Combined database and TIMSS 2011. The reasons why two different databases are included are:

- TIMSS and PIRLS 2011 International Combined database contains a sample of students that completed both surveys TIMSS and PIRLSS, reducing the sample size and, in consequence, a re-calculation of weights is needed for the construction of scales;
- TIMSS & PIRLS 2011 International Combined database does not include the separate scores for each of the TIMSS content domains. This information is only available in TIMSS 2011;
- TIMSS 2011 includes the specific items from the Home Questionnaire available in TIMSS and PIRLS 2011 International Combined database, however this does not include the specific ELT scale score.

For the present study we report results from the EU countries participating in the combined dataset. We also include Singapore (SNG) as a benchmark country because it performed particularly well in both mathematics and reading in 2011 (see Martin & Mullis, 2013 chapter 1, page 20). The inclusion of this benchmark country is mainly for comparison purposes. It allows for the comparison between each EU country with a non-EU country that is a top performer. Hence, the present study only includes the EU MS where the same sample of students completed both attainment surveys (TIMSS and PIRLS) and SNG. These countries are the following (see Table 2):

Table 2. Databases for the empirical analysis

EU countries/ jurisdictions	Austria; Croatia; Czech Republic; Finland; Germany; Hungary; Ireland; Italy; Lithuania; Malta; Poland; Portugal; Romania; Slovak Republic; Slovenia; Spain; Sweden
Benchmarking	Singapore

Our final working databases contain information of approximately 4,000 students from each EU country, with a total of around 76,000 students across the 17 EU countries, and more than 6,000 students in the case of Singapore[23].

4.4 Statistical analyses strategy

Given that early literacy skills have also been found to be associated with mathematical development (see subsection 2.2.2), we would expect that children's early literacy competences before they begin school influence their later mathematical performance. Nevertheless, and as proposed by the recent theoretical models of Krajewski & Schneider (2009b) and LeFevre et al. (2010), we would also expect that the impact of early literacy

[23] The National Defined Population for Singapore's sample for TIMSS2011 covers 90% to 95% of National Target Population (not the 100%).

competences before school onset on later mathematical school attainment is limited to certain aspects of school mathematics.

This report addresses three different research questions:

1) Do the ENT and the ELT scales predict math attainment at 4th grade?
2) Do the individual items of the ELT scale have differential relationships with math attainment at 4th grade?
3) Do the individual items of the ELT scales have differential relationships with the different TIMSS content domains at 4th grade?

To address these questions we used a tree-step statistical approach which is fully described in the following three subsections.

4.4.1 Model 1: Do the ENT scale and the ELT scale predict math attainment at 4th grade?

We first examine whether the early numeracy and the early literacy scales predict unique variance in students overall TIMSS scores using TIMSS and PIRLS 2011 Combined International database. Previous studies have examined the relationship between the ENT scale and students' overall TIMSS scores (Mullis et al., 2012), and the relationship between the ELT scale and students' overall PIRLS scores (Mullis et al., 2012). Nevertheless recent theoretical models of early mathematical development suggest that early literacy skills are independent predictors of mathematical development (Krajewski & Schneider, 2009b; LeFevre, 2010). We conducted Ordinary Least Square regressions to explore whether both, the ENT scale and the ELT scale, predict unique variance of the students TIMSS overall scores when entered alone and also together in the regression model. We control for several students and background characteristics:

- Sex of the student (from the student questionnaire)
- Home resources for learning (from the Learning to Read Survey)
- Parents' highest education level (from the Learning to Read Survey)
- Parents' highest occupation level (from the Learning to Read Survey)
- Student years of pre-school attendance (from the Learning to Read Survey)

If early literacy competences predict a significant amount of variance of students' overall mathematical scores (even when early numeracy competences are also included in the statistical model) it would suggest that early literacy practices are also important for mathematical attainment.

The empirical model is defined as follows:

$$\boldsymbol{MACH_{4rd} = \alpha_1 + \beta_1 * ELT_{PS} + \beta_2 * ENT_{PS} + \beta_3 * Controls} + \in$$

Where $MACH_{4rd}$ refers to the overall TIMSS score of the student, ELT and ENT are the quantitative scales related to the child performance in literacy and numeracy tasks, respectively. Control variables are constructed as follows:

- Sex of the student[24] is a dummy variable where 1 refers to girls and 0 to boys.

- Home resources for learning scale[25] is a quantitative variable based on students' responses to questions concerning the availability of home resources (number of

[24] Based on the variable ASBG01.
[25] Based on the variable ASBGHRL.

books, and number of home study supports) and their parents' responses to questions in the PIRLS Home Questionnaire[26].

- Parents' highest levels of occupation[27] are dummy variables distinguishing between the following occupations: professional, small business owner, clerical, skilled worker, general labourer, never worked outside home and not applicable.

- Parents' highest levels of education[28] are dummy variables distinguishing between the following levels: tertiary (university or higher), secondary (post-secondary but not university, upper secondary, lower secondary), primary (some primary, lower secondary) and not applicable.

- Student attendance to pre-school[29] variable is a three dummy variable capturing: not attendance, less than three years of attendance and three or more years of attendance.

4.4.2 Model 2: Do the individual items of the ELT scale have differential relationships with overall math achievement at 4th grade?

We examine whether specific items of the ELT scale predict unique variance in students overall TIMSS scores. Previous studies have suggested that different types of early home learning activities have differential impact on different learning contents (LeFevre et al., 2002; Phillips & Lonnigan, 2009). A limited body of research has recently suggested that this is also true for early numeracy home learning activities (LeFevre et al., 2010; Skwarchuk et al., 2014). We conduct Ordinary Least Square regressions to explore whether the individual items that compose the ELT Scale (i.e. recognise most of the letters of the alphabet, read some words, read sentences, write letters of the alphabet and write some words) predict unique variance of the students overall TIMSS scores. We control for the same variables as in model 1 (i.e. sex of the student, home resources for learning, parents' highest education and occupation level, and student years of pre-school attendance). Additionally, we control for the ENT scale score from the Learning to Read Survey. This allows us to examine whether certain early literacy practices predict significant and independent variance in students' overall TIMSS scores when early numeracy competences are also included in the model. TIMSS and PIRLS 2011 report[30] used the ELT and the ENT scales and therefore no specific relationships between each of the ELT scale items and later mathematical attainment could be reported. Nevertheless, this in-depth analysis provides an indication of whether certain specific early literacy competences are more strongly associated to mathematical attainment. We would expect that early literacy items in the ELT scale related to reading competences (i.e. read some words and read sentences) to be better predictors than items related to writing competences (i.e. recognise most of the letters of the alphabet, write letters of the alphabet and write some words).

[26] This construct is composed by different questions: a) number of books in the home (students) including 5 possible options (0-10; 11-25: 26-100; 101-200; more than 200), number of home study supports (students) with three possible answers (none; internet connection or own room; both), number of children's books in the home (parents) with 5 possible options (0-10; 11-25: 26-50; 51-100; more than 100), highest level of education of either parent (parents) with 5 options (finished some primary or lower secondary or did not go to school, finished lower secondary, finished upper secondary, finished post-secondary education or finished university or higher) and highest level of occupation of either parent (parents) with four options (has never worked outside home for pay, general labourer, or semi–professional; clerical; small business owner; or professional).

[27] Based on the variable ASDHOCCP.

[28] Based on the variable ASDHEDUP.

[29] Based on the variable ASDHAPS.

[30] http://timssandpirls.bc.edu/timsspirls2011/downloads/TP11_Relationship_Report.pdf

The mathematical model used in this case is:

$$MACH_{4rd} = \alpha_1 + \beta_{1j} * ELT_{jPS} + \beta_2 * ENT_{PS} + \beta_3 * Controls + \in$$

Where $MACH_{4rd}$ refers to the overall TIMSS score of the student, ELT_j are each of the items that compose the Early Literacy Scale (i.e. Recognise most of the letters of the alphabet, read some words, read sentences, write letters of the alphabet and write some words), the ENT scale is the quantitative scale related to the child performance in numeracy tasks and controls refer to the same variables as model 1. In this case, due to the high correlation among the ELT scale items (Annex II), the influence of each item on TIMSS overall scores has been analysed in independent regressions model.

Specific items are introduced in the regression model as a dummy variables with the value 1 if parents answered that the child performed 'very well' or 'moderated well' and zero if the parents answered 'not very well' or 'not at all' for each activity before school onset.

4.4.3 Model 3: Do the individual items of the ELT scale have differential relationships with the different TIMSS content domains at the 4th grade?

We examine whether specific items of the ELT scale predict unique variance in students TIMSS domains scores. For the purpose of this report, we would be using the content domain classification (Number, Geometric Shapes and Measures, and Data Display) to examine the influence of early literacy competences in later mathematical attainment. We opted for the content domain classification because it is clear that items in the Number content domain require children to perform exact arithmetic and/or number fact retrieval to a much larger extent than items the other two content domains (Geometric Shapes and Measures domain and Data display domain) (see appendix I). Items in the Geometric Shapes and Measures draw to a larger extend on visuospatial skills and items in the Data display content domain require more abstract number processing such as relating numerical quantities. According to Dehaene and colleagues' work (1999, 2003) and to Krajewski and Schneider's (2009b); and LeFevre et al.'s (2010) models, literacy skills would support aspects of mathematics that rely on phonological processing abilities (items in the number content domain), but not other aspects of mathematics that draw to more on other skills (visuospatial and quantitative skills). We would expect that children who had less chances to learn and practice early literacy skills before school onset, would perform more poorly than their peers on the number content domain items whilst the impact of early literacy practices in the home for items pertaining the other two TIMSS content domains should be limited. We conducted Ordinary Least Square regressions to explore whether each of the items that compose the ELT scale predict unique variance of the students Number, Geometric Shapes and Measures, and Data Display content domains' scores of TIMSS. We control for the same variables as in model 2 (i.e. sex of the student, home resources for learning, parents' highest education level, parents' highest occupation level, student years of pre-school attendance and the ENT scale score). This would allow us to determine whether certain early literacy competences before school onset predict significant and independent variance of students' specific mathematical abilities when early numeracy competences are also included in the model. Hence, it would provide an indication of the specific relationships between distinct early literacy competences and different aspects of mathematical performance.

In this case the model to analyse is:

$$MACH_{k4rd} = \alpha_{1i} + \beta_{1j} * ELT_{jPS} + \beta_2 * ENT_{PS} + \beta_3 * Controls + \in$$

Where $MACH_{k4rd}$ refers to the three TIMSS content domain scores, ELT_j are each of the items comprised in the ELT Scale, ENT is the quantitative scale related to the child performance in numeracy tasks and controls refer to the same variables as model 2.

5 Results

5.1 Introduction

This section presents the descriptive statistics and data analyses results of the study. It is divided in two main sections. First, it presents the descriptive statistics for the main variables used in the regression models. These include the results for the dependent variables of the study; overall TIMSS scores and TIMSS 2011 content domains scores (i.e. Number, Geometric Shapes and Figures, and Data Display) obtained by 4th grade students in the EU as a whole, by EU MS and in SNG. This section then includes the descriptive statistics results for the independent variables (i. e. the ENT and ELT scales' scores) and for the individual items comprised in the ELT scale. Descriptive statistics of control variables (sex, home resources for learning, parents' highest level of occupation and highest level of education) are presented in Annex III. The second part of this chapter presents the results from the inferential statistics in relation to each of the research questions addressed in this report for EU as a whole as well as for each EU MS included in the Combined TIMSS and PIRLS 2011 database and for the benchmark country (SNG).

5.2 Descriptive statistics

5.2.1 TIMSS scores: Overall TIMSS scores and by TIMSS content domains

Graph 1 shows the results for the TIMSS overall scores[31]. The average overall TIMSS scores for the EU as a whole was 506.58 (SD=71.61). PL, RO, ES, HR, MT and SE obtained average scores below this value, ranging from 481.16 (SD=69.06) for PL to 503.94 (SD=62.51) in the case of SE. SNG scored higher (M=605.79; SD=74.70) than any EU MS, followed by FI (M=545.44; SD=64.63). IE, DE, PT and LT scored above 520 points on average (MIE=527.40; SDIE=74.23; MDE=527.74; SDDE=58.36; MPT=581.16; SDPT=69.06; MLT=533.69; SDIE=70.38). The rest of the EU countries (SK, IT, AT, CZ, SI and HU) above the EU average obtained average scores between 500 and 520.

Graphs 2-4 show the results for the TIMSS content domains scores[32]. When examining the average scores by TIMSS content domains students in EU scored higher in the Data Display domain (Graph 4) (M=508.75; SD=83.35) than in the Number domain (Graph 2) (M=506.12; SD=69.55) and Geometric Shapes and Figures domain (Graph 3). DE, FI and PT had the highest scores in the Data Display domain (M_{DE}=545.70; SD_{DE}=70.69; M_{FI}=550.59; SD_{FI}=66.38; M_{PT}=548.44; SD_{PT}=68.96, see Graph 4) (M=507.52; SD=78.14). RO, ES, HR and PL had the lowest scores in all the three TIMSS content domains (see Graph 2), while IE, LT and FI had the highest scores in the Number domain (M_{IE}=532.79; SD_{IE}=74.61; M_{LT}=537.44; SD_{LT}=68.90; M_{FI}=545.27; SD_{FI}=67.56, see Graph 2).

Some countries performed above the EU average in certain domains while performing below the EU average for other(s). These are the cases of IT that only scored below the EU average in Data Display (M=494.51; SD=66.69), SE that only scored below the EU average in Geometric Shapes and Figures (M=499.51; SD=63.23) and SI that only scored below the EU average in Number domain (M=503.09; SD=67.47). SK scored

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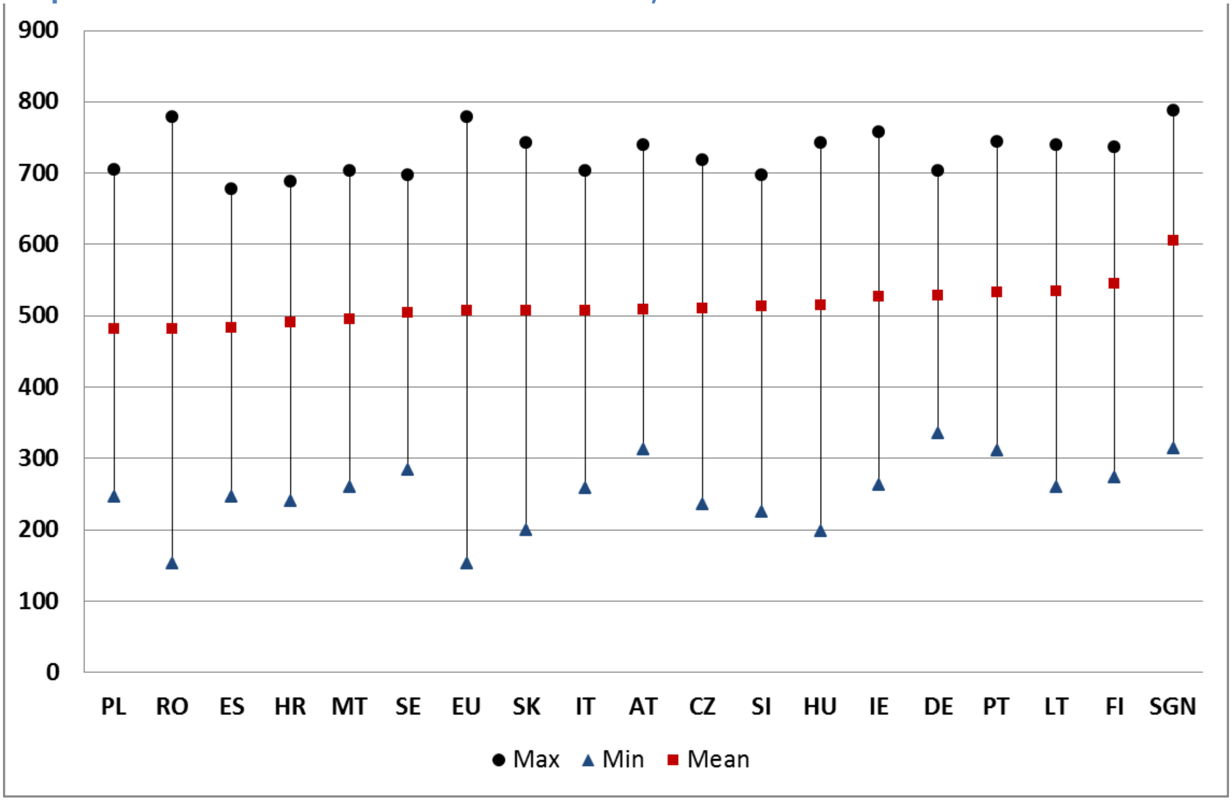
[31] Values are calculated as the average of the five plausible values for the overall TIMSS scores. Total students weight applied.

[32] Values are calculated as the average of the five plausible values for TIMSS content domains scores. Total students weight applied.

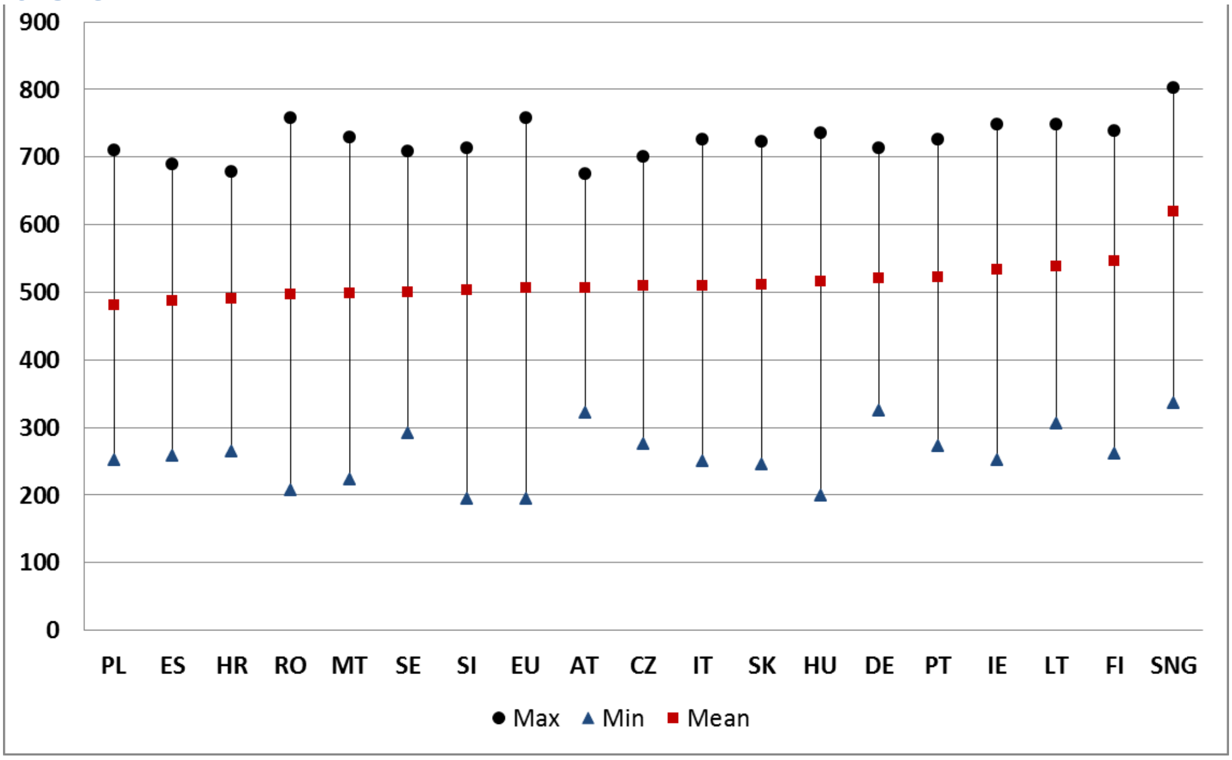
below the EU average in Data Display and in Geometric Shapes and Figures (M_{DATA}=504.10; SD_{DATA}=84.66; M_{GEO}=499.90; SD_{GEO}=79.41) but above the European average in the Number domain (M=511.38; SD=72.37).

Graph 1. TIMSS overall scores for EU as a whole, for each EU MS and for SNG



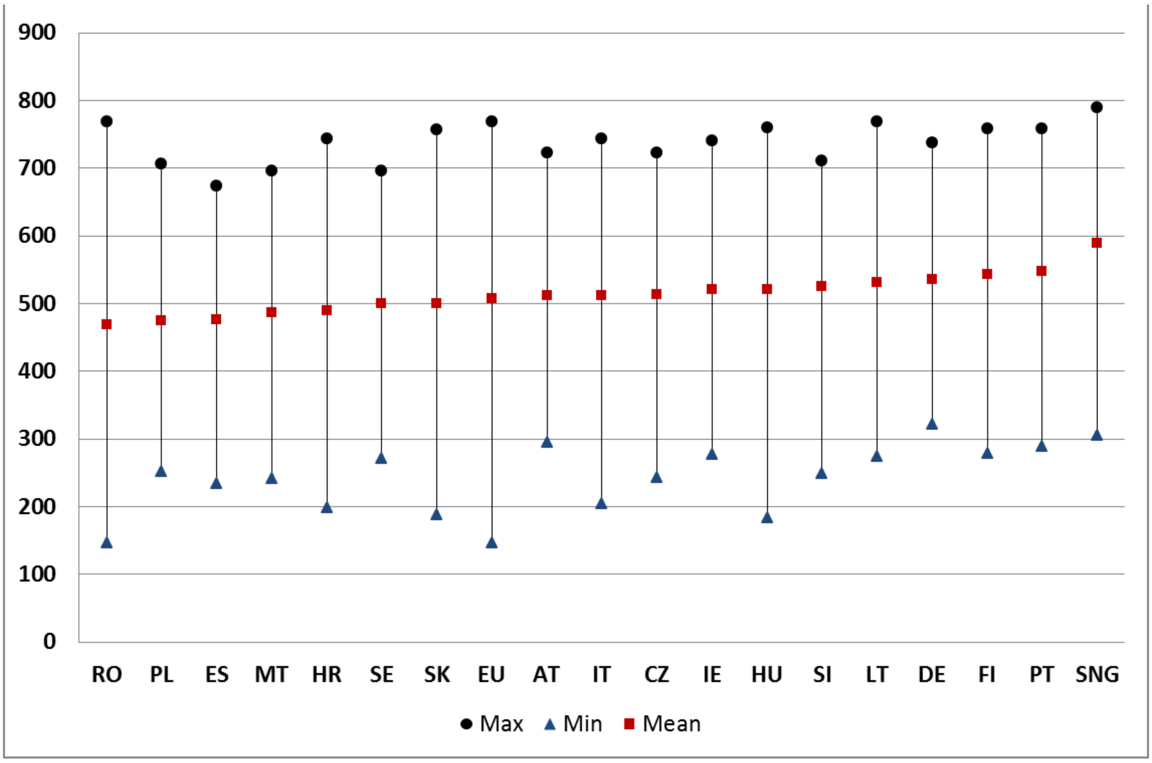
Source: Authors' own elaboration from TIMSS 2011

Graph 2. TIMSS Number Content Domain Scores for EU as a whole, for each EU MS and for SNG



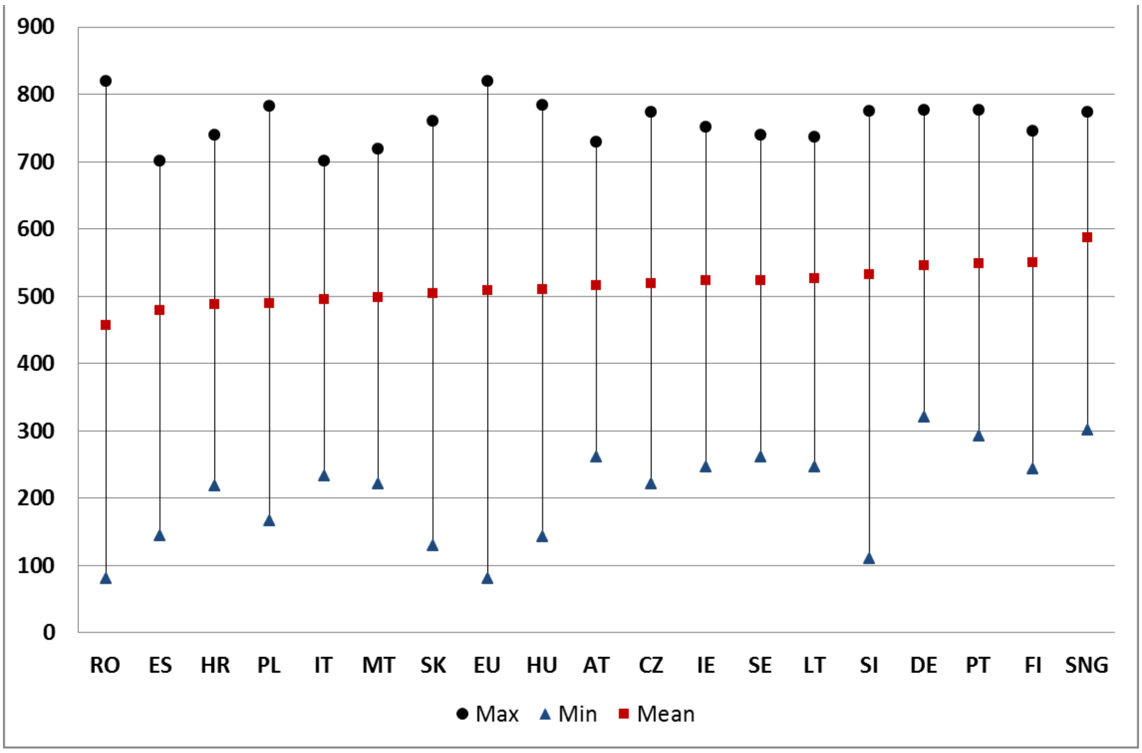
Source: Authors' own elaboration from TIMSS 2011

Graph 3. TIMSS Geometric Shapes and Figures Content Domain Scores for EU as a whole, for each EU MS and for SNG



Source: Authors' own elaboration from TIMSS 2011

Graph 4. TIMSS Data Display Domain Scores for EU as a whole, for each EU MS and for SNG



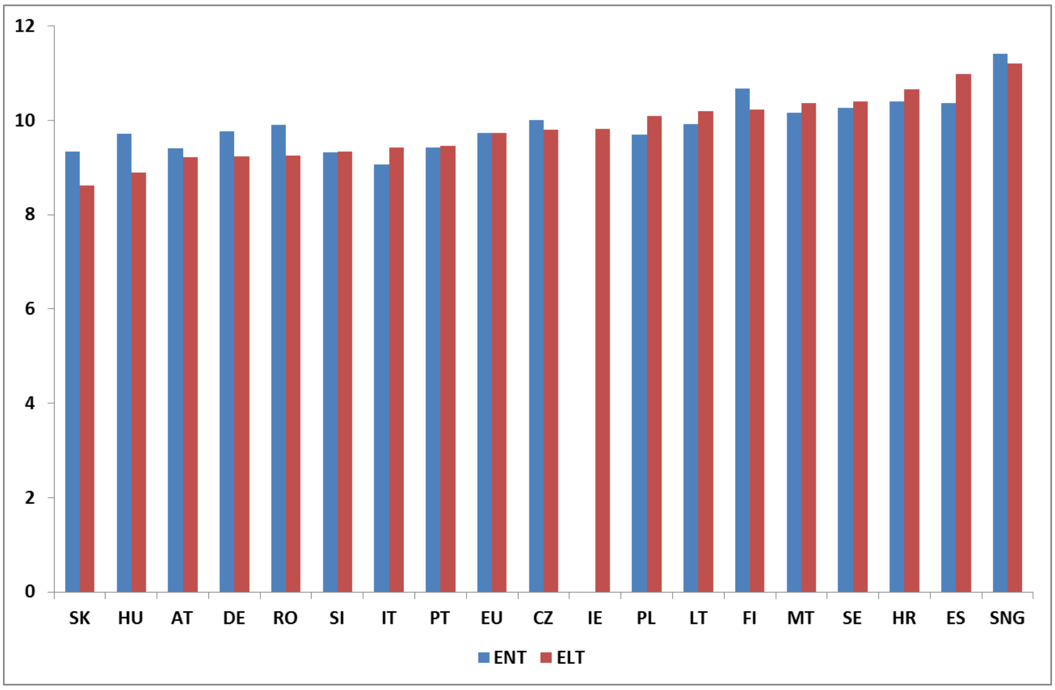
Source: Authors' own elaboration from TIMSS 2011

5.2.2 The ELT scale and the ENT scale scores

This section describes the results for the ELT and ENT scales for the EU as a whole and by EU MS and benchmark country. Because we aim to analyse the effects of the ELT scale as a whole and its individual items on TIMSS scores, descriptive statistics for each of the items in the ELT scale are also reported.

Graph 5 includes the average scores for the ENT and ELT scales for every EU MS as well as for EU as a whole and for the benchmark country. Countries are presented in ascending order by the average score in the ELT scale. The EU average is 9.73 (SD=1.95) in ELT scale and 9.74 (SD=1.92) in ENT scale. Similar scores are reported in SI where the average score for the ENT scale was 9.32 (SD=1.87) and the average score for the ELT was 9.35 (SD=2.02). SNG obtained the highest score in the ELT scale (*M*=11.20; SD=1.61), followed by ES, HR, SE, MT, FI, LT, PL and IE (M_{ES}=10.98; SD_{ES}=1.82; M_{HR}=10.66; SD_{HR}=1.72; M_{SE}=10.40; SD_{SE}=1.78; M_{MT}=10.37; SD_{MT}=1.77; M_{FI}=10.22; SD_{FI}=1.99; M_{LT}=10.20; SD_{LT}=1.55; M_{PL}=10.09; SD_{PL}=1.87; SD_{IE}=1.76). SK and HU obtained the lowest average scores, obtaining both less than 9 points in this scale (SD_{SK}=1.86 and SD_{HU}=2.09). In the majority of the countries below the EU average (i.e. SK, HU, AT, DE and RO) the ENT average score is more than half point higher than the one reported for ELT (for example in SK M_{ENT}=9.34 while M_{ELT}=8.62). This result is also evident in CZ and FI but with lower differences between both values (in CZ M_{ENT}=10.01 while M_{ELT}=9.80 and in FI M_{ENT}=10.67 while M_{ELT}=10.22). On the contrary, IT, PT, PL, LT, MT, SE, HR and ES scored higher on the ELT scale than on the ENT scale, being ES the country with the largest difference (M_{ENT}=10.37 versus M_{ELT}=10.98).

Graph 5. ENT and ELT scores for The EU as a whole, for every EU MS and for SNG

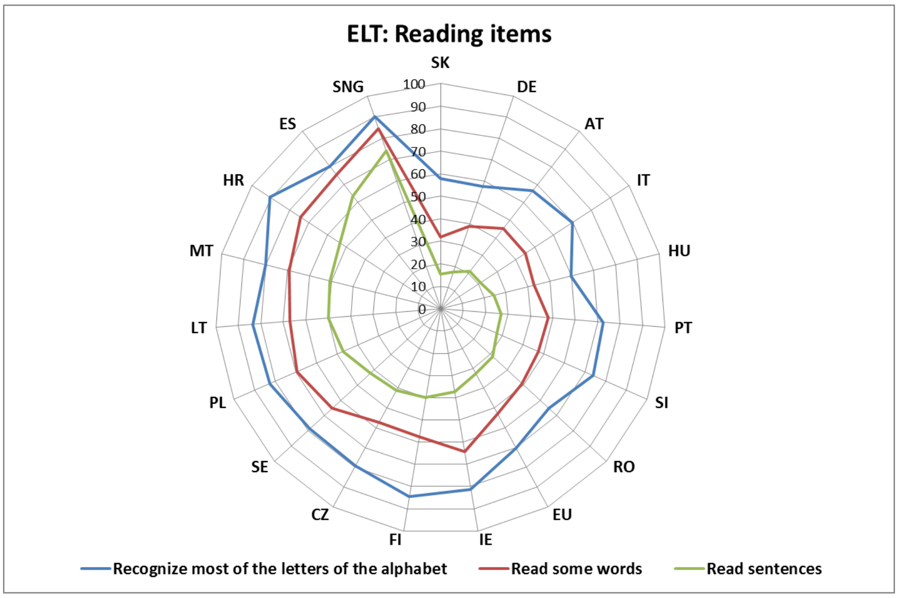


Source: Authors' own elaboration from TIMSS 2011 ENT scale and TIMSS&PIRLS 2011 ELT scale.
Note. ENT for IE is not included due to the lack of data.

Graph 6 and Graph 7 present the average percentage of parents reporting 'Well' for each item in the ELT scale. Graph 6 includes the percentage for those items related to reading ability (i.e. recognise most of the letters of the alphabet, read some words and read sentences) and Graph 7 the ones related to writing abilities (i.e. to write letters of the alphabet and to write some words).

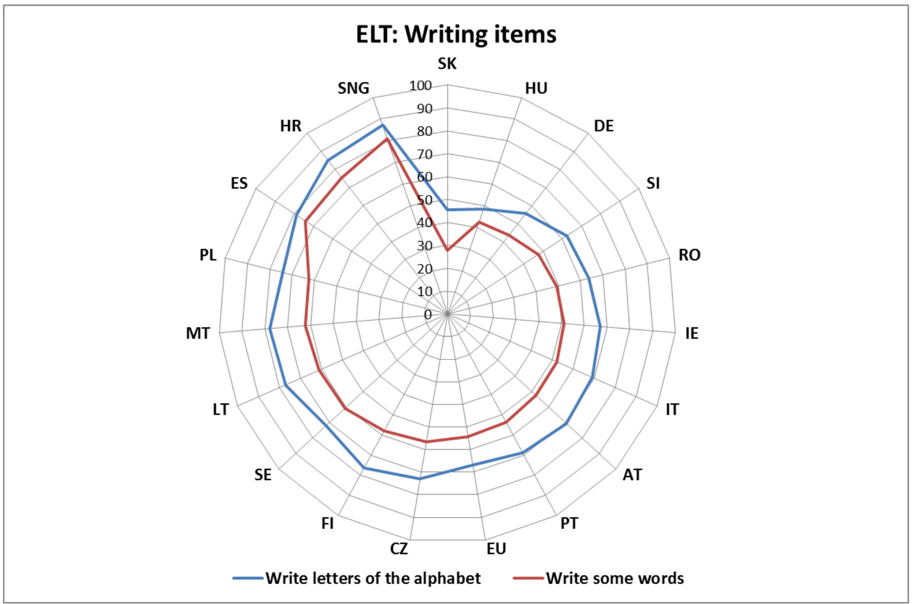
Graph 6 shows that in all EU countries as well as in SNG, the reading ability better performed by students before that began school was "to recognise most letters of the alphabet", with parents reporting that more than 70% of students did 'Well' this activity on average. In contrast, for the item "reading some words" and for the item "read some sentences", 53% and 32.8% of students were identified by their parents as performing "well", respectively. Only HR (90.5%) had a higher percentage of students recognising letters in the alphabet better than the benchmark country (90.2%). In ES, MT, IE, PL, LT, FI and HR more than 80% of the students could recognise well most of the letters of the alphabet, while less than 60% were able to do this well in DE, SK and HU, as reported by their parents. HR and ES had the highest percentage of students being able to read some words (more than 70%) or reading sentences (more than 52%) well while SK and DE had the lowest percentages of students doing these reading abilities well (less than 40% for reading some words and less than 20% for reading sentences).

Graph 6. Percentage of parents reporting that their children performed 'Well' in the ELT scale items related to reading abilities



Source: Authors' own elaboration from TIMSS 2011.

Graph 7. Percentage of parents reporting that their children performed 'Well' in the ELT scale items related to writing abilities



Source: Authors' own elaboration from TIMSS 2011.

With regards to the items related to writing abilities (see Graph 7), parents across the EU reported higher percentages for the item "writing letters of the alphabet" (66.8%) than for "writing some words" (54.4%). All EU countries obtained lower percentages in writing abilities than the benchmark country. In SK, HU, DE, SI and RO the percentage of students writing of the alphabet 'well' were below the EU average (with values ranging from 45.5% in SK to 63.5% in RO). FI, LT, MT, ES and HR presented the highest percentages with more than three quarters of students being able to "read letters of the alphabet" well as reported by parents. In CZ, FI, SE, LT, MT, PL, ES and HR the percentage of students who could "read some words" well before starting school was above 70%.

5.3 The ELT scale and the ENT scale as independent predictors of maths achievement (from TIMSS&PIRLS 2011)

5.3.1 Effects of the ELT scale and the ENT scale on TIMSS overall scores in EU

Results for the effects of the ELT and the ENT scales on students' overall TIMSS scores for the EU as a whole are presented in Table 3. Controls included sex of the student, home resources for learning, student attendance to pre-school (whether less than three years or more than three years) and parents' highest education and highest occupation level.

Table 3. Effects of the ENT and the ELT Scales Predicting Overall TIMSS Scores and Controlling for Background Characteristics

	(ENT scale)	(ELT scale)	(ENT+ELT)
ENT	8.98*** (0.32)		6.56*** (0.38)
ELT		7.91*** (0.31)	4.17*** (0.36)
Sex (Ref. category: Girl)	5.00*** (0.55)	6.66*** (0.56)	5.78*** (0.56)
Home resources	14.16*** (0.64)	15.09*** (0.63)	14.09*** (0.64)
Student attendance to Pre-School Education (Ref. cat. No attendance)			
3 years or more	4.98** (1.51)	5.47*** (1.52)	4.42* (1.51)
Less than 3 years	2.15 (1.43)	2.42[t] (1.44)	1.73 (1.42)
Parents' highest education level (Ref. category: Never worked outside)		Included	
Parents' highest occupation level (Ref. category: Primary)		Included	
N	65,820	65,509	65,405
R^2	0.29	0.28	0.30

Note: Models include constant and country dummies. Standard errors (SE) between brackets. [t]p-value<0.1; *p-value<0.05; **p-value<0.01; ***p-value<0.001.
Source: Authors' own elaboration from PIRLS&TIMSS 2011.

The ENT scale and the ELT scale make significant independent contributions to overall TIMSS scores for the EU as a whole. When entered as a single predictor both, the ENT scale (Column I) and the ELT scale (Column II) predict a significant proportion of variance in the overall TIMSS scores (β_{ENT}=8.98, SE_{ENT}=0.32 and β_{ELT}=7.91, SE_{ELT}=0.31, respectively). When entered together as predictors in the regression model (Column III), both scales still affect the overall TIMSS scores (β_{ENT} = 6.56, SE_{ENT} = 0.38 and β_{ELT} = 4.17, SE_{ELT} = 0.36). Therefore the ELT scale still predicts later math scores even after controlling for the effects of early numeracy knowledge.

Regarding the association between students' sex and maths scores, male students obtained better overall TIMSS scores than female students overall in the EU. Examining students' background variables relating to the home learning environment, the expected relationships with the outcome measure were observed. Both, having more home resources and having attended preschool for three years or more (compared to not having attended preschool at all) were positively associated with overall TIMSS scores in the EU. All categories of parents' education and occupation[33] were included as controls in the regression model and results (although not presented here for conciseness) suggest that the higher the level of education is, the higher the math scores obtained by the students (β = 4.32, SE = 0.05 in secondary education and β = 7.63, SE = 0.09 in tertiary education). In relation to parents' occupations, being a worker in clerical occupations or a skilled worker were the categories more related to children's mathematical attainment (β = 5.51, SE = 0.06 in clerical occupations and β = 4.53, SE = 0.04 in skilled worker occupation).

5.3.2 Effects of the ELT scale and ENT scale on TIMSS overall scores in every EU MS and Singapore

Results for the effects of the ELT and the ENT scales on students' overall TIMSS scores for the different EU MS and the benchmark country (SNG) are presented in Table 4. As in the equations for the EU as a whole (see section 5.2.1), controls included sex of the student, home resources for learning, student attendance to pre-school and parents' highest education and highest occupation level.

The ENT scale predicted a significant proportion of variance in the overall TIMSS scores for every EU MS and SNG when entered alone in the regression model (Column I). It is worth noting that only in FI the effect of the ENT scale on overall TIMSS scores (β = 14.91; SE = 0.83) was slightly higher than the effect found for the benchmark country (β = 14.46; SE = 1.09). Other countries showing an important effect of the ENT scale on overall TIMSS scores were HR (β = 13.18; SE = .30) and LT (β = 12.14; SE = .92). The lowest effects of ENT in overall TIMSS score was found in PT (β = 6.87; SE = 1.24) and SK (β = 6.89; SE = 1.16).

The ELT scale also predicted a significant proportion of variance in the overall TIMSS scores for every EU MS and SNG when entered alone in the regression model (Column II). In this case, not only in FI (β = 13.73; SE = 0.65) but also in LT (β = 16.74; SE = 1.09) the ELT scale predicts a greater proportion of variance in TIMSS overall scores than in the benchmark country (β = 13.23; SE = 1.05). Across the EU MS, high coefficients for ELT appeared also in HR (β = 12.62; SE = 0.68) and SE (β = 12.47; SE = 0.85), whilst the lowest influence appeared in PT (β = 3.80; SE = 1.24) and AT (β = 4.73; SE = 0.70).

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[33] Parents' occupations are: professional, small business owner, clerical, skilled worker, general laborer, never worked outside home and not applicable.

Table 4. Effects of the ENT Scale and the ELT Scale on Overall TIMSS Scores while Controlling for Background characteristics for every EU MS and SNG

Country	ENT	N	R^2	ELT	N	R^2	ENT	ELT	N	R^2
AT	8.20*** (0.64)	3,909	0.26	4.73*** (0.7)	3,917	0.22	7.99*** (0.72)	0.37 (0.8)	3,887	0.26
HR	13.18*** (0.3)	4,248	0.25	12.62*** (0.68)	4,220	0.24	8.62*** (0.96)	7.93*** (0.8)	4,220	0.27
CZ	9.52*** (0.81)	4,173	0.24	6.63*** (0.69)	4,149	0.22	7.88*** (0.97)	3.12*** (0.79)	4,144	0.24
FI	14.91*** (0.83)	4,117	0.26	13.73*** (0.65)	4,118	0.27	9.36*** (1.07)	9.16*** (0.86)	4,110	0.31
DE	8.30*** (0.9)	2,644	0.27	5.18*** (0.77)	2,641	0.24	7.65*** (0.97)	1.27 (0.82)	2,663	0.27
HU	9.01*** (0.87)	4,498	0.40	4.91*** (0.68)	4,466	0.38	8.42*** (0.88)	1.01 (0.62)	4,466	0.40
IE	7.61*** (1.07)	3,838	0.23	6.54*** (1.09)	3,818	0.22	6.00*** (1.15)	2.64* (1.18)	3,816	0.23
IT	7.86*** (0.83)	3,484	0.13	7.71*** (0.79)	3,457	0.13	5.24*** (0.98)	4.45*** (0.93)	3,457	0.14
LT	12.14*** (0.92)	4,113	0.28	16.74*** (1.09)	4,102	0.30	7.27*** (0.88)	12.5*** (1.02)	4,101	0.32
MT	7.30*** (1.00)	2,612	0.17	7.72*** (0.99)	2,607	0.18	4.35*** (1.03)	5.40*** (1.02)	2,602	0.19
PL	10.48*** (0.73)	4,579	0.30	10.01*** (0.68)	4,548	0.30	6.92*** (0.88)	5.73*** (0.8)	4,548	0.31
PT	6.87*** (1.24)	3,493	0.17	3.8** (1.24)	3,463	0.15	6.87*** (1.18)	-0.01 (1.3)	3,460	0.17
RO	9.08*** (1.49)	4,202	0.27	6.68*** (1.7)	4,155	0.26	7.99*** (1.73)	1.64 (1.98)	4,154	0.27
SK	6.89*** (1.16)	5,168	0.23	5.43*** (1.08)	5,110	0.21	5.87*** (1.09)	1.99^{t} (1.07)	5,108	0.23
SI	9.58*** (0.75)	4,033	0.27	9.35*** (0.56)	4,020	0.28	5.27*** (1.00)	6.23*** (0.76)	4,018	0.29
ES	8.38*** (0.88)	3,414	0.23	11.37*** (0.86)	3,404	0.27	2.75*** (0.96)	9.83*** (0.94)	3,397	0.27
SE	11.16*** (1.04)	3,295	0.26	12.47*** (0.85)	3,314	0.28	6.06*** (1.24)	9.14*** (1.24)	3,281	0.30
SNG	14.46*** (1.09)	5,716	0.27	13.23*** (1.05)	5,693	0.28	7.75*** (1.03)	9.94*** (1.00)	5,688	0.30

Note: Models include as control variables sex, Home resources for learning, Parents' highest education level, Parents' highest occupation level, Student attendance pre-school. Standard errors (SE) between brackets. ^{t}p-value<0.1; *p-value<0.05; **p-value<0.01; ***p-value<0.001.
Source: authors' own elaboration from PIRLS&TIMSS 2011.

When both the ENT and the ELT scales were entered together as predictors in the regression model, the ENT scale always predicted a significant proportion of variance in overall TIMSS scores for every EU MS and for SNG. The effect of the ELT scale when entered together with the ENT scale in the regression model varied across countries. Two overall trends can be identified among all EU MS. First, in MT, LT, SI, ES, SE and SNG both scales were significant, with the ENT scale having a greater effect in overall TIMSS scores than the ELT scale. Second, in AT, DE, HU, RO and PT, the ELT scale did no longer predict variance in TIMSS overall scores when entered together with the ENT scale in the regression model, suggesting that great part of the variance predicted by the ELT when entered as a single predictor was shared with the ENT scale. Compared with SNG, only in LT the effect of ELT scale was higher than in SNG when the ENT scale is included in the statistical model.

5.4 Individual items of the ELT scale as predictors of maths achievement (from TIMSS 2011)

5.4.1 Effects of the individual ELT scale items on TIMSS overall scores in EU as a whole

Table 5 shows the results for the effects of the each of the items comprised in the ELT scale on students' overall TIMSS scores for the EU as a whole. Controls included sex of the student, home resources for learning, student attendance to pre-school (whether less than three years or more than three years), parents' highest education and highest occupation level, and students' ENT scores. Because of the highly correlation between the items comprised in the ELT scale (see correlations in Annex II), five individual regressions were conducted to examine the specific influence of each item on TIMSS overall scores. For each regression model, one individual item of the ELT scale was included as a predictor.

Results in Table 5 show that each of the items comprised in the ELT scale were positively associated with TIMSS overall scores for EU when entered individually in the regression model. Items asking about the students reading abilities (i.e. ability to recognise most of the letters of the alphabet, being able to read some words and being able to read sentences) were more strongly related to TIMSS overall scores than items asking about students' writing abilities (ability to write some letters of the alphabet and ability to write some words). Comparing different items of ELT, results suggest that "read some words" ($\beta = 4.44$, SE = 0.63) had higher influence than "recognise some letters" ($\beta = 4.09$, SE = 0.69), while "read sentences" ($\beta = 3.76$, SE = 0.59) was the item with the lower beta value across the three reading abilities items. Within the written abilities, "write some words" ($\beta = 1.94$, SE = 0.54) had higher effect on maths achievement than "write only letters" ($\beta = 1.71$, SE = 0.56).

With regards to the control variables, as in the previous section (section 5.2), being a male, having more learning resources at home and attending pre-school for 3 years or more were positively associated with students TIMSS overall scores.

5.4.2 Effects of ELT scale items on TIMSS overall scores in every EU MS and Singapore

Table 6 shows the results for the individual regressions examining the effects of each of the items comprised in the ELT scale on TIMSS overall scores for each EU MS and the benchmark country (SNG). For each regression model (Column I to Column V), an individual item in the ELT scale was included as a predictor. Controls included sex of the student, home resources for learning, student attendance to pre-school (whether less than three years or more than three years), parents' highest education and highest occupation level, and students' ENT scores.

Table 5. Individual items of the ELT scale as predictors of overall TIMSS scores at 4th grade in EU as whole (2011)

	Recognise letters	Read words	Read sentences	Write letters	Write some words
ELT					
Recognise most of the letters of the alphabet	4.09*** (0.69)				
Read some words		4.44*** (0.63)			
Read sentences			3.76*** (0.59)		
Write letters of the alphabet				1.71** (0.56)	
Write some words					1.94*** (0.54)
ENT scale	6.61*** (0.35)	6.40*** (0.36)	6.63*** (0.38)	7.00*** (0.34)	6.91*** (0.34)
Sex (Ref. category: Girl)	4.09*** (0.69)	4.93*** (0.53)	4.80*** (0.52)	4.76*** (0.52)	4.79*** (0.53)
Home resources	14.43*** (0.68)	14.38*** (0.68)	14.38*** (0.67)	14.41*** (0.67)	14.41*** (0.68)
Student attendance to Pre-School Education (Ref. cat. No attendance)					
3 years or more	4.04*** (1.2)	4.15*** (1.21)	4.37*** (1.20)	4.26*** (1.21)	4.26*** (1.21)
Less than 3 years	1.35 (1.21)	1.37 (1.20)	1.59 (1.20)	1.46 (1.20)	1.52 (1.20)
Parents' highest education level (Ref. category: Never worked outside)	Included	Included	Included	Included	Included
Parents' highest occupation level (Ref. category: Primary)	Included	Included	Included	Included	Included
N	62293	61962	61758	62103	62062
R^2	0.27	0.27	0.27	0.27	0.27

Note: Models include constant and country dummies. Standard errors (SE) between brackets. [t]p-value<0.1; *p-value<0.05; **p-value<0.01; ***p-value<0.001.
Source: authors' own elaboration from TIMSS 2011.

Table 6. Effects of the individual items in the ELT scale on overall TIMSS scores at 4th grade in EU MS and SNG (2011).

	Recognise letters	Read words	Read sentences	Write letters	Write some words
AT	1.14	0.15	0.84	-3.45**	-1.66
	(1.19)	(1.22)	(1.53)	(1.00)	(1.18)
HR	6.97***	8.93***	7.82***	4.94**	5.92***
	(2.07)	(1.62)	(1.17)	(1.84)	(1.65)
CZ	3.97*	3.05*	1.10	0.29	0.27
	(1.83)	(1.43)	(1.46)	(1.8)	(1.43)
FI	10.29***	8.59***	10.99***	6.02**	5.35**
	(1.88)	(1.65)	(1.44)	(1.94)	(1.7)
DE	0.33	0.71	0.93	0.50	1.16
	(1.36)	(1.22)	(1.53)	(1.26)	(1.23)
HU	1.06	1.45	0.77	-1.97^{t}	-2.35^{t}
	(1.2)	(1.14)	(1.87)	(1.18)	(1.31)
IT	6.08***	6.09***	3.16^{t}	1.65	2.06
	(1.81)	(1.60)	(1.71)	(1.57)	(1.42)
LT	17.23***	12.85***	11.69***	6.04***	7.71***
	(2.77)	(1.49)	(1.29)	(1.56)	(1.77)
MT	12.94***	6.32***	4.3**	5.59*	4.3**
	(2.47)	(1.77)	(1.64)	(2.42)	(1.65)
PL	5.76**	6.07***	3.94**	2.89^{t}	1.10
	(2.00)	(1.41)	(1.26)	(1.49)	(1.32)
PT	2.75	1.49	0.47	-0.30	-0.56
	(2.10)	(1.57)	(1.51)	(2.09)	(1.87)
RO	0.28	3.85	1.72	-2.32	-0.32
	(3.86)	(2.91)	(2.31)	(3.59)	(2.79)
SK	4.18**	3.88*	3.48*	2.22	0.53
	(1.48)	(1.94)	(1.74)	(1.43)	(1.42)
SI	8.01***	6.92***	7.11***	4.71**	5.21***
	(1.77)	(1.44)	(1.27)	(1.58)	(1.52)
ES	13.96***	10.32***	8.68***	9.07***	8.69***
	(2.74)	(2.06)	(1.65)	(2.24)	(1.81)
SE	6.31**	10.08***	7.6***	6.15**	5.73**
	(2.17)	(1.56)	(1.52)	(2.26)	(1.85)
SNG	16.79***	16.19***	12.99***	10.13***	11.05***
	(2.53)	(1.94)	(1.70)	(2.27)	(1.61)

Note: IE is not included due to the lack of data. Models include constant. Standard errors (SE) between brackets. ^{t}p-value<0.1; *p-value<0.05; **p-value<0.01; ***p-value<0.001.
Source: authors' own elaboration from TIMSS 2011.

Table 6 shows that influence of the early literacy practices on TIMSS overall scores varies across countries. Nevertheless, three clear trends can be observed in the data. First, there is a group of countries (i.e. HR, FI, LT, MT, ES, SE, SI and SNG) where all individual literacy items were significant predictors of later mathematical achievement. In all these countries the ELT scale predicted significant unique variance TIMSS overall score when the ENT scale scores were included in the regression model. In a second group of countries (i.e. AT, DE, HU, PT and RO) the early literacy practices were not significant positive predictors of later mathematical achievement. This sub-set of countries is the same as those where the ELT scale did no longer predict TIMSS overall score when the ENT scale scores were included in the regression model. In a third group of countries (IT, PL and SK), the three early reading abilities were significant predictors of TIMSS overall scores while either one or neither of the early writing abilities were significant. CZ did not fall in any of these groups. In this country only the items of "recognising letters" and "reading words" were significantly and positively associated with TIMSS overall scores.

When comparing the EU MS results to those of the benchmark country (SNG), it can be noted that the effects of all reading and writing abilities items are more strongly related to maths for SNG than for any EU MS, with the exception of the relationship between "recognising some letters" in LT (β_{LT} = 17.23, SE_{LT} = 2.77 versus β_{SNG} = 16.79, SE_{SNG} = 2.53).

5.5 Effects of the individual items of the ELT scale on maths achievement at 4th grade by each TIMSS content domain in EU (from TIMSS 2011)

5.5.1 Effects of the individual early literacy items on each TIMSS content domain in EU as a whole

Results for the EU as a whole on the effects of each of the items comprised in the ELT scale on students' scores on each TIMSS content domain are presented in Table 7 for TIMSS Number content domain, Table 8 for TIMSS Geometric Shapes and Figures content domain and Table 9 for TIMSS Data Display content domain. As in the previous models controls included sex of the student, home resources for learning, student attendance to pre-school, parents' highest education and occupation level, and students' ENT scores.

All items of the ELT scale significantly and positively predict the three TIMSS content domains scores with the only exception of "writing letters of the alphabet" that did not affect significantly the Geometric Shapes and Measures domain scores. The influence of the early literacy practices varies across the TIMSS content domains; the effect of each individual item of the ELT scale on the Data Display domain scores was always greater than for the other two domains (i.e. Number and Geometric Shapes and Measures), being Geometric Shapes and Measures the domain where the items had the smallest effects. The beta values for the Data Display domain ranged from 4.26 to 4.76 for the items related to reading abilities and, 2.23 and 2.31 for the items related to writing abilities. In contrast, the beta values for the Geometric Shapes and Measures domain ranged from 3.04 to 3.67 for the items related to reading abilities and, 1.16 and 1.17 for the items related to writing abilities.

Table 7. Effects for the Individual Items of the ELT Scale as Predictors of TIMSS Scores on the TIMSS Number Content domain in EU as a Whole (2011)

Number	**Recognise letters**	**Read words**	**Read sentences**	**Write letters**	**Write some words**
ELT					
Recognise most of the letters of the alphabet	3.88*** (0.77)				
Read some words		4.14*** (0.70)			
Read sentences			3.42*** (0.55)		
Write letters of the alphabet				1.54* (0.66)	
Write some words					1.96*** (0.64)
ENT	6.44*** (0.36)	6.27*** (0.37)	6.51*** (0.38)	6.84*** (0.37)	6.71*** (0.38)
N	62,293	61,962	61,758	62,103	62,062
R^2	0.24	0.24	0.24	0.23	0.23

Note: IE is not included due to the lack of data. Models include as control variables sex, Home resources for learning, Parents' highest education level, Parents' highest occupation level, Student attendance pre-school as well as country dummies. Standard errors (SE) between brackets. [t]p-value<0.1; *p-value<0.05; **p-value<0.01; ***p-value<0.001. Source: authors' own elaboration from TIMSS 2011.

It is worth noting that for every domain and just like when predicting overall TIMSS scores, the items related to reading abilities always had greater effects than the items related to writing abilities for the three TIMSS content domains.

Table 8. Effects for the Individual Items of the ELT Scale as Predictors of TIMSS Scores on the TIMSS Geometric Shapes and Measures Content Domain in EU as a Whole (2011)

Geometric Shapes and Measures	(I)	(II)	(III)	(IV)	(V)
ELT					
Recognise most of the letters of the alphabet	3.41*** (0.75)				
Read some words		3.67*** (0.68)			
Read sentences			3.04*** (0.72)		
Write letters of the alphabet				1.16 (0.72)	
Write some words					1.7** (0.62)
ENT	6.43*** (0.36)	6.26*** (0.37)	6.47*** (0.36)	6.8*** (0.35)	6.66*** (0.33)
N	62,293	61,962	61,758	62,103	62,062
R^2	0.28	0.28	0.28	0.27	0.28

Note: IE is not included due to the lack of data. Models include as control variables sex, Home resources for learning, Parents' highest education level, Parents' highest occupation level, Student attendance pre-school as well as country dummies. Standard errors (SE) between brackets. [t]p-value<0.1; *p-value<0.05; **p-value<0.01; ***p-value<0.001.
Source: authors' own elaboration from TIMSS 2011.

Table 9. Effects for the Individual Items of the ELT Scale as Predictors of TIMSS Scores on the TIMSS Data Display Content Domain in EU as a Whole (2011)

Data Display	(I)	(II)	(III)	(IV)	(V)
ELT					
Recognise most of the letters of the alphabet	4.59*** (0.93)				
Read some words		4.76*** (0.92)			
Read sentences			4.26*** (0.87)		
Write letters of the alphabet				2.23** (0.68)	
Write some words					2.31*** (0.68)
ENT	7.04*** (0.41)	6.86*** (0.4)	7.07*** (0.37)	7.42*** (0.37)	7.36*** (0.37)
N	62,293	61,962	61,758	62,103	62,062
R^2	0.28	0.28	0.28	0.28	0.28

Note: IE is not included due to the lack of data. Models include as control variables sex, Home resources for learning, Parents' highest education level, Parents' highest occupation level, Student attendance pre-school as well as country dummies. Standard errors (SE) between brackets. [t]p-value<0.1; *p-value<0.05; **p-value<0.01; ***p-value<0.001.
Source: authors' own elaboration from TIMSS 2011.

5.5.2 Effects of the individual early literacy items on each TIMSS content domain in every EU MS and Singapore

Results for the effects of each of the items comprised in the ELT scale on students' scores on each TIMSS content domain (i.e. Number, Geometric Shapes and Figures, and Data Display) for the different EU MS and the benchmark country (SNG) are presented in Table 10, Table 11 and Table 12. These include regression models where Number (Table 10), Geometric Shapes and Measures (Table 11), and Data Display (Table 12) domains are the dependent variables respectively.

Table 10. Effects for the Individual items of the ELT scale as predictors of TIMSS Number scores for every EU MS and SNG(2011)

	Recognise letters	Read words	Read sentences	Write letters	Write some words
AT	0.66 (1.23)	0.28 (1.20)	1.31 (1.53)	-3.04* (1.00)	-1.54 (1.10)
HR	6.91*** (2.08)	7.79*** (1.50)	7.30*** (1.22)	4.7** (1.57)	6.15*** (1.28)
CZ	3.62[t] (2.01)	3.30* (1.42)	1.07 (1.35)	0.42 (1.74)	0.14 (1.43)
FI	9.40** (2.93)	9.38*** (1.79)	11.83*** (1.5)	5.35* (2.09)	5.46** (1.76)
DE	0.07 (1.4)	0.78 (1.36)	0.98 (1.51)	0.23 (1.37)	1.21 (1.47)
HU	1.27 (1.39)	1.14 (1.22)	0.80 (1.75)	-2.18[t] (1.24)	-2.64[t] (1.48)
IT	6.15*** (1.78)	5.45*** (1.53)	3.07[t] (1.64)	1.74 (1.68)	2.24 (1.46)
LT	15.41*** (2.94)	11.16*** (1.66)	10.79*** (1.46)	5.25*** (1.59)	7.01*** (1.73)
MT	13.60*** (2.90)	6.80** (2.16)	3.94* (1.58)	7.23** (2.67)	4.86* (1.91)
PL	5.74** (2.07)	5.28** (1.76)	2.98* (1.29)	2.24 (1.61)	0.59 (1.42)
PT	2.74 (2.13)	1.04 (1.81)	0.07 (1.51)	-0.97 (2.18)	-0.32 (1.91)
RO	0.25 (3.74)	4.03 (2.83)	1.18 (2.38)	-2.27 (3.4)	-0.53 (2.62)
SK	3.20* (1.42)	3.93[t] (2.04)	3.46* (1.91)	1.50 (1.44)	0.70 (1.53)
SI	6.68*** (1.70)	6.90*** (1.43)	7.37*** (1.50)	4.42* (2.00)	5.49*** (1.62)
ES	13.06*** (2.77)	9.09*** (2.16)	7.48*** (1.76)	8.87*** (2.30)	8.64*** (2.03)
SE	6.39** (2.46)	11.10*** (2.00)	8.33*** (1.71)	6.59** (2.16)	6.26*** (2.03)
SNG	16.27*** (2.65)	15.80*** (1.94)	12.47*** (1.79)	9.19*** (2.34)	10.60*** (1.67)

Note: IE is not included due to the lack of data. Models include as control variables sex, Home resources for learning, Parents' highest education level, Parents' highest occupation level, Student attendance pre-school as well as country dummies. Standard errors (SE) between brackets. [t]p-value<0.1; *p-value<0.05; **p-value<0.01; ***p-value<0.001.
Source: authors' own elaboration from TIMSS 2011.

Table 10, Table 11 and Table 12 show that influence of the early literacy practices is fairly similar across the different TIMSS content domains, although a few variations can be observed across countries. In countries where each of the five individual items comprised in the ELT scale were significant predictors of the overall TIMSS score (i.e. HR, FI, LT, MT, ES, SI, SE and SNG), these items were still significant predictors for each TIMSS content domain. Similarly, where none of the five individual items comprised in the ELT scale were significant positive predictors of the overall TIMSS score (i.e. AT, DE, HU, PR and RO), none of the five individual items were significant positive predictors for any TIMSS content domain.

Table 11. Effects for the Individual Items of the ELT Scale as Predictors of TIMSS Geometric Shapes and Figures Scores for Every EU MS and SNG (2011)

	Recognise letters	Read words	Read sentences	Write letters	Write some words
AT	0.68 (1.73)	-0.08 (1.51)	0.97 (1.85)	-4.35* (2.00)	-2.07 (1.36)
HR	9.39** (3.25)	10.48*** (2.13)	9.20*** (1.33)	6.82** (2.18)	7.52*** (1.75)
CZ	3.68[t] (2.11)	2.42 (1.63)	0.83 (1.66)	0.59 (2.14)	0.30 (1.79)
FI	8.01** (2.58)	8.22*** (1.77)	11.09*** (1.36)	3.98* (1.92)	4.84** (1.81)
DE	-0.01 (1.50)	1.06 (1.55)	0.99 (1.64)	0.86 (1.67)	1.46 (1.34)
HU	0.89 (1.73)	0.72 (1.46)	-0.3 (2.00)	-2.37[t] (1.32)	-3.54 (1.55)
IT	5.78* (2.43)	4.97* (2.00)	2.63 (2.09)	0.86 (1.85)	2.04 (1.90)
LT	16.78*** (3.41)	12.22*** (1.88)	11.27*** (1.55)	6.21*** (1.74)	7.55*** (1.52)
MT	11.68*** (3.28)	4.99* (2.12)	2.77[t] (1.61)	5.70* (2.65)	3.69* (1.81)
PL	4.55* (1.95)	4.28** (1.55)	3.23[t] (1.71)	1.54 (1.45)	0.76 (1.59)
PT	3.92[t] (2.34)	1.61 (1.94)	-0.45 (1.68)	-0.30 (2.63)	-0.01 (2.27)
RO	0.41 (4.17)	3.22 (3.31)	1.57 (2.8)	-3.94 (4.04)	-1.22 (2.86)
SK	3.08[t] (1.62)	3.91[t] (2.11)	3.17 (2.02)	1.39 (1.63)	0.64 (1.69)
SI	6.45*** (1.81)	6.12*** (1.36)	6.66*** (1.31)	3.78[t] (2.14)	5.15*** (1.55)
ES	12.75*** (2.96)	8.40*** (2.23)	7.19*** (1.85)	9.57*** (2.42)	8.35*** (2.11)
SE	5.36* (2.43)	10.10*** (2.29)	7.64*** (1.56)	4.44* (1.76)	5.16** (1.85)
SNG	16.31*** (2.64)	15.99*** (2.04)	12.81*** (1.96)	9.67*** (2.24)	10.74*** (1.84)

Note: IE is not included due to the lack of data. Models include as control variables sex, Home resources for learning, Parents' highest education level, Parents' highest occupation level, Student attendance pre-school as well as country dummies. Standard errors (SE) between brackets. [t]p-value<0.1; *p-value<0.05; **p-value<0.01; ***p-value<0.001.
Source: authors' own elaboration from TIMSS 2011.

However, some variations were found for the group of countries where a sub-set of items predicted TIMSS overall score (IT, PL and SK). In the case of IT, none of the writing abilities were significant predictors of any of the TIMSS content domain scores. For PL, "writing letters" was a significant predictor of overall TIMSS overall scores and also predicted Data Display domain scores (see Table 12), but it was not a significant predictor for either Number (see Table 10) or Geometric Shapes and Figures (see Table 11). In SK "writing letters" was a significant predictor of TIMSS overall scores and also predicted Number domain score (see Table 10), but failed to predict at a significant level the other two domains. Finally, in CZ "recognising letters" and "reading words" were the only significant predictors of TIMSS overall scores and also of the Number domain score, while only "recognising letters" was a significant predictor of the Geometric Shapes and Figures domain and only "reading words" was a significant predictor of the Data Display domain.

Table 12. Individual items of the ELT scale as predictors of TIMSS Data Display scores in 4th grade students in EU MS (2011)

	Recognise letters	Read words	Read sentences	Write letters	Write some words
AT	-0.47 (1.63)	-0.72 (1.87)	0.60 (2.52)	-5.48*** (2.00)	-2.52 (1.62)
HR	7.87* (3.18)	9.99*** (2.37)	9.07*** (1.91)	6.07** (2.34)	7.57*** (2.03)
CZ	3.78 (2.55)	3.52[t] (2.11)	1.94 (2.12)	0.94 (2.10)	0.16 (2.03)
FI	9.15*** (2.76)	8.58*** (1.98)	11.4*** (1.56)	5.4* (2.28)	4.85** (1.79)
DE	0.04 (2.02)	1.94 (2.54)	1.66 (2.09)	0.65 (1.82)	0.63 (1.86)
HU	1.25 (1.88)	1.71 (1.74)	0.92 (2.32)	-1.66 (1.77)	-2.84 (2.17)
IT	5.83** (2.08)	5.13** (1.81)	2.44 (2.25)	1.51 (1.65)	2.16 (1.52)
LT	17.73*** (3.02)	12.79*** (1.74)	11.81*** (1.56)	6.93*** (1.79)	8.22*** (1.93)
MT	13.33*** (3.12)	6.67** (2.28)	4.97** (1.70)	7.14** (2.68)	4.14* (1.99)
PL	7.68*** (2.31)	7.17*** (2.00)	5.26** (1.90)	4.29* (2.25)	2.23 (1.91)
PT	3.68 (2.45)	1.24 (1.80)	-0.10 (1.54)	0.58 (2.01)	-0.84 (1.94)
RO	2.78 (4.76)	3.87 (3.51)	1.78 (3.11)	-2.28 (4.65)	0.54 (3.00)
SK	3.45* (1.61)	4.24[t] (2.52)	3.54[t] (2.02)	1.27 (1.79)	0.07 (1.89)
SI	9.66*** (2.62)	8.12*** (1.97)	7.58*** (1.82)	5.42* (2.42)	7.05*** (2.13)
ES	14.77*** (3.71)	9.99*** (2.49)	9.86*** (1.94)	10.34*** (2.61)	9.94*** (2.16)
SE	8.85*** (2.54)	13.28*** (2.40)	9.42*** (1.61)	9.16*** (2.72)	8.98*** (2.4)
SNG	16.55*** (2.61)	15.39*** (1.91)	11.95*** (1.75)	10.09*** (2.3)	10.55***(1.86)

Note: IE is not included due to the lack of data. Models include as control variables sex, Home resources for learning, Parents' highest education level, Parents' highest occupation level, Student attendance pre-school as well as country dummies. Standard errors (SE) between brackets. [t]p-value<0.1; *p-value<0.05; **p-value<0.01; ***p-value<0.001.
Source: authors' own elaboration from TIMSS 2011.

6 Conclusions

6.1 Summary of the findings

The present work examined whether early numeracy and literacy competences in children before they start school as reported by their parents can predict their later mathematical attainment at 4^{th} grade. Different studies have demonstrated that early numeracy and literacy skills are good predictors of students' future school attainment. However, already at school entry there are large differences in the level of numeracy and literacy competences among children. This suggests that by the start of formal schooling, some children lack knowledge and practice of basic skills and therefore are at a disadvantage in comparison to their peers from very early on. Thus, it is important to identify the specific early pedagogical practices that can better enhance future learning from a very early age to inform ECEC policy and improve ECEC educational practices.

We used the Combined dataset of the Trends in International Mathematics and Sciences Study (TIMSS) and the Progress of International Reading Literacy Study (PIRLS), including the Learning to Read Survey, to examine the extent to which early numeracy and literacy competences predict later mathematical attainment. We also examined whether distinct early literacy competences have differential relationships with mathematical attainment overall as well as with different aspects of mathematics. We opted for TIMSS and PIRLS 2011 surveys to address these research questions because in 2011 both attainment surveys were distributed to a large sample of 4^{th} grade students in different countries. These studies do not only provide overall scores but also sub-scales scores for different learning domains in mathematics. Additionally, these large-scale studies also gather data on students' background characteristics, home learning environment and previous (before they began school) literacy and numeracy competences. Last, TIMSS and PIRLS data allow for the examination of relationship between variables for every participating country as well as for groups of countries. Here we provided the results for the EU as a whole, and also by EU MS and for SNG. The latter we used it as a benchmark country because students scored particularly high on both TIMSS and PIRLS in 2011.

The three specific research questions addressed in the current study were:

1) Do composite scores of early numeracy and early literacy tasks before school onset (as reported by parents) predict math attainment at 4th grade?

2) Do individual early literacy competences (as reported by parents) have differential relationships with overall math attainment at 4th grade?

3) Do individual early literacy practices have differential relationships with the different TIMSS content domains at 4th grade?

We conducted ordinary least square regressions using students' early literacy and numeracy abilities as the independent variables, and students TIMSS overall scores and TIMSS sub-scales scores on the different content domains as the dependent variables. We controlled for several student background characteristics in the statistical models such as sex of the student, home resources for learning, parents' highest education and highest occupation level, and student years of pre-school attendance.

In line with previous research (Anders et al., 2013; Blevins-Knabe et al., 2007) we found that a better home learning environment (indexed here as having more home resources for learning) and that preschool attendance (OECD, 2013; Rossbach et al., 2008) were positively associated with better mathematical attainment. We also found positive relationships between the level of education of the parents and parents having higher skilled jobs, and children's mathematical attainment as reported in previous studies (Anders et al., 2013; Larson et al., 2015).

More related to the present study aims, results indicated that early numeracy competences predict later mathematical attainment in the EU as a whole and also in every EU MS and SNG. However, although the effects of early literacy competences on later mathematical attainment were positive and significant for the EU as a whole, these effects were variable and not always significant for the individual countries. We also found that for certain EU MS specific literacy competences had differential relationships with mathematical attainment overall and with distinct aspects of mathematics at 4th grade. Nevertheless, overall results showed a stronger influence of early reading abilities than of early writing abilities on later mathematical performance. Results are discussed in more detail in the following sub-sections.

6.1.1 Do early numeracy and early literacy competences before school onset (as reported by parents) predict math attainment at 4th grade?

We were interested in determining whether early numeracy and early literacy abilities before school onset as reported by parents were good predictors of students' mathematical performance at 4th grade using the ELT and the ENT scale as predictor variables and TIMSS overall maths scores as outcome variables. We examined these relationships in three different steps.

First, we examined whether students' scores on the ENT scale predicted their TIMSS overall scores. In line with our hypothesis, this was true for the EU as a whole as well as for every EU MS and SNG. This corroborates previously reported positive associations between parental reports on children's early numeracy abilities before or at school onset and their later mathematical performance over the school years (LeFevre et al., 2009; LeFevre et al., 2010; Figueredo et al., 2001; Kleemans et al., 2012; Young-Loveridge, 2004; Ramani & Siegler, 2008; Siegler & Ramani, 2008; Skwarchuk et al., 2014; Skwarchuk et al., 2014).

Second, we examined whether students' scores on the ELT scale as reported by their parents predicted their TIMSS overall scores. We were particularly interested in exploring this relationship because recent theoretical models of early mathematical development suggest that verbal abilities before the start of school influence children's later numeracy skills and mathematical performance (Krajewski & Schneider, 2009; LeFevre et al., 2010). Interestingly, we found that for the EU as whole and in every EU MS and SNG, the ELT scale predicted unique variance in students' TIMSS overall scores. This also aligns with very recent research findings that have reported positive associations between parent's reports on children's early literacy competences and later mathematical performance (Anders et al., 2013; LeFevre et al., 2010; LeFevre et al., 2009) and adds evidence to the proposal that early literacy skills influence mathematical development (De Smedt et al., 2010; Krajewski & Schneider, 2009; Koponen et al., 2013; Purpura et al., 2011; Simmons & Singleton, 2008, 2009; Soto-Calvo et al., 2015).

Third, we examined whether students' scores on the ELT scale and on the ENT scale were unique predictors of overall TIMSS scores once they are both included in the statistical model. We know from recent limited body of research that both, early numeracy and early literacy competences predict later mathematical performance on standardised tests (LeFevre et al., 2009; Moll et al., 2105; Purpura et al., 2011). Nevertheless these empirical studies covered a short developmental period. It is worthwhile to examine the relative impact that each type of early skills make on mathematical attainment over a longer time gap to determine whether these effects are long-lasting or dissipate over the very early years of schooling. Here we found that for EU as a whole, both the ENT and the ELT scales were unique predictors of TIMSS overall scores when entered together in the statistical model. Nevertheless, although this was also true for the majority of the EU MS and SNG, it was not true for a subset of EU MS (namely AT, DE, HU, PT and RO).

6.1.2 Do individual early literacy competences before school onset (as reported by parents) have differential relationships with overall math attainment at 4th grade?

We were interested in determining whether distinct early literacy abilities before school onset differentially predicted mathematical performance at 4th grade using the individual items comprised in the ELT scale as predictors and TIMSS overall maths scores as outcome variables. In these analyses we not only controlled for a comprehensive set of students' background characteristics but also for their scores on the ENT scale (because it was a significant predictor for the EU as a whole and for every EU MS and SNG even when ELT scores were included in the model). Previous research examining the effects of early literacy competences on mathematical performance has particularly focused on early reading abilities (LeFevre et al., 2009; Moll et al., 2015; Purpura et al., 2011; Skwarchuk et al., 2014). Nevertheless, the ELT scale of the Learning to Read Survey includes items on early reading abilities (i.e. recognise most of the letters of the alphabet, read some words, read sentences) as well as on early writing abilities (write letters of the alphabet and write some words). In line with existing theoretical proposals and empirical studies that argue that certain mathematical abilities draw on verbal skills (De Smedt et al., 2010; Hecht et al., 2001; Krajewski & Schneider, 2009a,b; Koponen et al., 2013; Moll et al., 2015; Simmons & Singleton, 2008, 2009; Simmons et al., 2008; Soto-Calvo et al., 2015) we expected early reading abilities to have greater effects on later mathematical performance than early writing skills. Results confirmed these differential contributions favouring early reading abilities for the EU as a whole. However, when examining these relationships for each EU MS and SNG, different patterns of relationships appeared. Unsurprisingly, in those countries where the ELT scale was not a significant predictor of TIMSS overall scores when the ENT was included in the model, none of the ELT individual items predicted maths attainment. More interestingly, the ELT items made differential contributions to TIMSS overall scores in countries where the ELT scale was a significant predictor; while for a subset of these countries all ELT items were significant predictors, for another sub-set of countries it was early reading abilities in particular (and not early writing abilities) that predicted TIMSS overall scores.

6.1.3 Do individual early literacy competences before school onset (as reported by parents) have differential relationships with the different TIMSS content domains at 4th grade?

Lastly, we were interested in determining whether distinct early literacy abilities before school onset differentially predicted performance on different mathematical contents at 4th grade using the individual items comprised in the ELT scale as predictors and the three TIMSS content domains scores as outcome variables. In these analyses we again controlled for the comprehensive set of students' background characteristics and their ENT scale scores. It has been suggested that verbal abilities are recruited when performing specific mathematical tasks in adults (see Dehaene et al., 2003) and in children (De Smedt et al., 2010; Krajewski & Schneider, 2009a,b; LeFevre et al., 2010; Simmons & Singleton, 2008, 2009; Soto-Calvo et al., 2015). Using the TIMSS content domain sub-scale categorisation we hypothesised that items in the ELT scale would be better predictors of the TIMSS number domain scores (in which items test, among other mathematical aspects, exact arithmetic) than of the other two domains (i.e. Geographic Shapes and Figures and Data Display domains) in which items seem to draw to a larger extent on non-verbal abilities. Results showed that in the EU as a whole the ELT scale items were better predictors of the TIMSS Data Display domain, so our hypothesis needs to be rejected. Additionally no overall major differences were found when determining the influence of the ELT scale items on TIMSS overall scores than when the TIMSS content domains scores were used as outcome measures.

6.2 Implications for EU policy and practice

ECEC outcomes are the actual or intended short-term and long-term changes arising from the provision of ECEC services and that benefit children, their families, communities and society (European Commission, 2014). ECEC provision has three clear objectives with regards to children attending ECEC:

- The acquisition of non-cognitive skills and competences;
- The successful transition to school;
- Participation in society and preparation for later life and citizenship.

In the present report we provide research-based evidence to directly or indirectly assist policy-makers towards achieving these three objectives.

Frist, this report informs on key basic competences that form the basics foundation for their later learning. Here we provided evidence that early numeracy abilities are good predictors of later mathematical performance in the EU as a whole and in every EU MS as well as in SNG. We also show that early literacy abilities are also good predictors of later mathematical performance overall and also in some EU MS. This highlights that the ECEC curricula must focus on education as much as on care. However, the national pre-primary curriculum in some EU MS still does not include mathematics and/or reading skills (see Mullis et al., 2012 and Mullis et al., 2012). Based on the present results and a solid body of empirical evidence (see section 2.2) it would be advisable to include these basic early academic skills in the ECEC primary curricula alongside the non-cognitive skills. For all these competences, the ECEC curricula should set clear goals, include specific instructional activities and assessment methods. Given the importance that the acquisition of knowledge and competences has during this early developmental period, ECEC staff and parents need to be informed and well prepared to provide children the best opportunities to acquire these basic skills and to monitor their progress with measurable learning outcomes.

Second, the negative effects of lack of basic numeracy and literacy skills at school entry are long-lasting in very young children (Aunola et al., 2004; Jordan et al., 2007). General and specific characteristics of the child and his background may contribute to the knowledge gap between good and poor performers. Nevertheless, recent studies provide a positive view on how to tackle these differences and level the field. For instance, a positive relationship has been demonstrated between ECEC attendance and mathematics performance while controlling for SES aspects in certain countries (Sandoval-Hernandez et al., 2013), suggesting that attending ECEC could narrow the competence gap explained by the different SES backgrounds in very young learners. Similarly, here we show that early literacy and numeracy competences are good predictors of later performance even when SES and other background characteristics are controlled for. This is indeed an important finding because it suggests that the existing gap in early competences among children, when linked to their SES and other background characteristics, could be potentially narrowed with effective early instruction and sufficient practice. However, there are still large differences in the starting age and length that children can attend ECEC across countries (see European Commission/EACEA/Eurydice/Eurostat, 2014). Ensuring that before school onset all young children receive adequate pedagogical instruction and practice their basic skills sufficiently could work as an effective strategy towards reducing the early gap between good and poor performers at school entry. This could also provide equal opportunities for school success from very early stages. Early childhood curricula and home pedagogical practices play a fundamental role towards achieving this aim. Also, as stressed by the ECEC quality theoretical frameworks described in this report (see section 3.3), a comprehensive, clear and well-designed ECEC curriculum may still not be effective if other key elements of the ECEC systems are not appropriately engaged. For instance, high-qualified ECEC staff and the engagement of families are crucial elements towards a high-quality ECEC system. The present results also suggest that ECEC staff and adults in the home learning environment can act as an excellent source of information and monitoring of the ECEC system.

Finally, children attendance to high-quality ECEC settings has been negatively associated to early school leaving. Good mathematical skills are viewed as an important requirement for students' successful integration in the society (see section 3.2.3).

6.3 Limitations of the study

The current findings inform about early literacy competences that predict later mathematical attainment and have clear implications for ECEC curricula and home practices. Nevertheless, the data used in this study has some limitations that need to be acknowledged.

First, PIRLS & TIMSS data is of a cross-sectional nature. Thus, it allows for the exploration of relationships between predictor and outcome variables but not for the directionality of these relationships. In this study we cannot provide evidence of causal relationships between predictor and outcomes. We found that early numeracy and literacy competences before the start of school are good overall predictors of later mathematical performance in children and also that the influence of early literacy competences on later mathematical attainment varies between different countries. Nevertheless, we cannot confirm that children's early numeracy and literacy competences are the cause of their better mathematical attainment later on. However, the fact that the predictor variables related to early competences of the children (before they began school) whilst the outcome variables related to their performance at a much later developmental stage (4^{th} grade), strongly suggests this directionality.

Second, while students' scores on TIMSS are a direct measure of their ability, the predictor and control variables used in this study are self-reported (by either students or their parents). This means that responses could be biased towards more socially preferable answers. Additionally, the data used as predictor variables refer to past information (before the child began school) and not concurrent (4^{th} grade). Therefore, there is the possibility of potential inaccuracies in these variables due to the large time gap elapsed between the two. Nevertheless the present results are in line with those from other survey studies (LeFevre et al., 2002; LeFevre et al., 2009; LeFevre et al., 2010; Figueredo et al., 2001; Kleemans et al., 2012; Young-Loveridge, 2004; Ramani & Siegler, 2008; Siegler & Ramani, 2008; Skwarchuk et al., 2014; Skwarchuk et al., 2014).

Third, it is also worth noting that certain variables used as control in the present study (i.e. home resources for learning and parents' highest levels of occupation and education) are concurrent with the outcome measures (TIMSS scores) and not with the predictor variables. Although research suggests that aspects of the home learning environment do not fluctuate greatly over the child early years (see Son & Morrison, 2010), controlling for students´ home resources for learning and parents' highest levels of occupation and education before they had not yet started school would be preferable

Fourth, although PIRLS and TIMSS provide a very comprehensive set of data by collecting contextual information via the background questionnaires (student, teacher, school and curriculum) and the Learning to Read Survey, it does not gather data on key cognitive skills that have been associated to school success in general as well as to early mathematical learning (e.g. general cognitive abilities and memory skills) nor on ECEC quality. Having access to this information could greatly complement the findings reported here.

Lastly, in the Learning to Read Survey parents are asked about how well their child could do early numeracy and literacy tasks before their child began school. Although they are also asked whether their child attended ECEC and for how long, we cannot be certain on whether the learning processes leading to the acquisition of these abilities took place in the ECEC setting, in the home environment or in both. It would be very useful for ECEC policy implementation to determine the extent of the influence of both the home learning environment and the preschool setting on early skills acquisition.

6.4 Recommendations

In this report we corroborate previous empirical findings that early competences are important towards later school success. Our findings suggest that the effects of these competences are long-lasting and independent of other child´s and context's characteristics. This highlights the importance of ensuring that all young children are provided access to adequate and effective learning environments from a very early age.

A key finding in this study is that children's early literacy competences have differential impact on mathematical outcomes across countries, being for certain EU MS not significant. This calls for caution when implementing educational policy based on identified best practices. Although peer learning is without a doubt a good strategy in order to improve educational policy, regional and cultural characteristics must be taken into account when implementing educational practices in different geographical and cultural settings.

An additional important finding is that it is worth examining the effects of construct measures as well as of individual items on learning outcomes. In this report we found that individual items of the ELT scale had differential relationships with mathematical scores, favouring those that related to early reading skills rather than those related to early writing skills. In order for educational policy to be efficient, the research-based evidence needs to be able to provide fine-grained analyses as much as general links between constructs.

Lastly, policy-makers and educational researchers need to bear in mind that learning is a complex build-up process and children develop new strategies as a result of their continuous learning process (see Dowker, 2005; McKenzie et al., 2003; Rasmussen et al., 2003). Here, we did not find remarkable differences when examining the relationship between the predictor variables with the overall score or the sub-scale scores in mathematics and rejected our experimental hypothesis (children who had less chances to learn and practice early literacy skills before school onset, would perform more poorly than their peers on the Number content domain items than on the Geographic Shapes and Measures and on the Data Display content domains items) based on a well-established theoretical model of mathematical cognition (Dehaene et al. 2003). Nevertheless, this two-point study covers a very large time gap. Thus, there is a possibility that the effects of early literacy practices on specific aspects of mathematics that require more verbal processing dissipate over time once children have learnt certain contents and have developed more efficient strategies to perform attainment tasks. In order to improve early education policy through research evidence, it is vital to have large comprehensive sets of longitudinal data with multiple time points over the early years. Particularly for ECEC policy implementation and practice, it would be very beneficial to determine the extent to which both the ECEC setting and the home learning environment enhance children's early competences.

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Annex

Annex I. PIRLS and TIMSS surveys

The Progress of International Reading Literacy Study (PIRLS)

PIRLS assesses 4th grade students' reading attainment every five years. The last PIRLS assessments took place in 2011. A total of about 325,000 students from 58 jurisdictions (49 countries and 9 benchmarking) participated in PIRLS 2011. Next table shows the list of countries that participated in PIRLS:

List of countries that participated in PIRLS 2011

EU countries/ jurisdictions	Austria; Belgium (French); Bulgaria; Croatia; Czech Republic; Denmark; England; Finland; France; Germany; Hungary; Ireland; Italy; Lithuania; Malta; Netherlands; Poland; Portugal; Romania; Slovak Republic; Slovenia; Spain; Sweden
Non-EU countries	Australia; Azerbaijan; Botswana; Canada; Chinese Taipei; Colombia; Georgia; Honduras; Hong Kong SAR; Indonesia; Iran, Islamic Republic of Israel; Kuwait; Morocco; New Zealand; Northern Ireland; Norway; Oman; Qatar; Trinidad and Tobago; United Arab Emirates; United States
Benchmarking countries	Alberta (Canada); Ontario (Canada); Quebec (Canada); Maltese (Malta); English/Afrikaans (South Africa); Andalusia (Spain); Abu Dhabi (UAE); Dubai (UAE); Florida (USA)

Students are asked to read story passages or texts and to respond to multiple-choice questions, constructed responses or to organise sentences related to the text in temporal order. Each student is asked to complete a session of maximum 80 minutes for the booklet (two passages), with an additional 15-30 minutes allotted for the student questionnaire. Each booklet contains the same number of four-choice and constructed-response items. One point is given for selecting the correct response in multiple choice items and one, two or three points are given for constructed-response items depending on the level of difficulty of the item.

The Trends in International Mathematics and Sciences Study (TIMSS)

TIMSS assesses 4th and 8th grade students' mathematics and science attainment every four years. The last TIMSS assessments took place in 2015. Because we are particularly interested in examining the relationships between different early pedagogical competences (including early literacy ones) and mathematical attainment in the current study, here we only provide the detailed description of the mathematic assessments in 2011. A total of about 600,000 students from 77 jurisdictions (63 countries and 14 benchmarking) participated in TIMSS 2011. See the following table shows the list of countries that participated in TIMSS survey.

List of countries that participated in TIMSS 2011

EU countries/ jurisdictions	Austria; Belgium (Flemish); Croatia; Czech Republic; Denmark; England; Finland; Germany; Hungary; Ireland; Italy; Lithuania; Malta; The Netherlands; Poland; Portugal; Romania; Slovak Republic; Slovenia; Spain; Sweden
Non-EU countries	Armenia; Australia; Azerbaijan; Bahrain; Botswana; Chile; Chinese Taipei; Georgia; Ghana; Honduras; Hong Kong SAR; Indonesia; Islamic Republic of Iran; Israel; Japan; Jordan; Kazakhstan; Republic of Korea; Kuwait; Lebanon; Macedonia; Malaysia; Morocco; New Zealand; Northern Ireland; Norway; Oman; Palestinian Nat'l Auth; Qatar; Russian Federation; Saudi Arabia; Serbia; Singapore; South Africa; Syrian Arab Republic; Thailand; Tunisia; Turkey; Ukraine; United Arab Emirates; United States; Yemen
Benchmarking	Abu Dhabi (UAE); Alabama (USA); Alberta (Canada); California (USA); Colorado (USA); Connecticut (USA); Dubai (UAE); Florida (USA); Indiana (USA); Massachusetts (USA); Minnesota (USA); North Carolina (USA); Ontario (Canada); Quebec (Canada)

There are 14 different booklets for TIMSS with interlinked items. Students are asked to complete one booklet that comprises the same number of mathematics and sciences items in two sessions of 36 min minutes each. The mathematic booklet contains the same number of items four-choice items and free response items. Free-response items are constructed-response items that require students to give a numerical result, provide a short explanation or description given in one or two phrases or sentences, complete a table, or provide a sketch. TIMSS questionnaire that assess three different content domains and three different cognitive domains, with every item in the booklet tapping one content domain and one cognitive domain. The relative weight of each content and cognitive domain is determined by education experts a priori. With regards to 4th grade assessments in 2011 in mathematics, the shares of score points for the content domains were: Number domain 50%, Geometric Shapes and Measures domain 35% and Data Display domain is 15%. The shares of score points for the cognitive domains were: Knowing domain 40%, Applying domain 40% and Reasoning domain 20%:

TIMSS Content and Cognitive domains 2011

TIMSS 2011 Mathematics Domains			
Content	**%**	**Cognitive**	**%**
Number	50%	Knowing	40%
Geometric Shapes and Measures	35%	Applying	40%
Data Display	15%	Reasoning	20%

TIMSS 2011 provides an overall score and a score for each content and cognitive domain of mathematics. The content domain classifies the questionnaire items in relation to the specific subject matter to be assessed within school mathematics. Therefore these categories divide the items according to their specific task demands. Each of these content domains is as well subdivided into different categories, which are listed below:

- **Number:** This content domain assesses number system understanding in a broad sense, including number meaning, number sequencing and number comparison, place-value number system, mathematical rules, pre-algebra concepts and performing arithmetic. This content domain includes four sub-areas; whole number, fraction and decimals, number sentences with whole numbers, and patterns and relationships.
- **Geometric Shapes and Measures:** This content domain assesses understanding of geometrical physical properties of two- and three-tridimensional figures such as lines, angles, areas and volumes as well as grasping the concept of symmetry and rotation. This content domain includes two sub-areas; points, lines and angles, and two- and three-dimensional shapes.
- **Data Display:** This content domain assesses the ability to read, interpret and compare numerical information represented or re-organised in graphs and charts. This content domain includes two sub-areas; reading and interpreting, and organizing and representing.

The cognitive domains classify the questionnaire items in relation to the type of thinking process required to answer the item. These are:

- **Knowing:** Refers to the numerical information and procedures the student's has learnt and that serves as a knowledge base to perform mathematics tasks. This cognitive domain is divided into four different sub-areas, i.e. Whole number, fractions and decimals, Number Sentences with Whole Numbers and Patterns and Relationships.
- **Applying:** Refers to the capability of the student to employ his or her numerical knowledge and understanding in a mathematical problem. This cognitive domain is divided into two different sub-areas, i.e. Points, Lines, and Angles and two- and three-dimensional Shapes.
- **Reasoning:** Refers to the student ability to utilize higher-order thinking to arrive to the solution of a mathematical problem that is unfamiliar or requires meta-cognitive processes. This cognitive domain is divided into two different sub-areas, Reading and Interpreting and Organizing and representing.

TIMSS 2011 Content Domains

	SUB-AREA	ITEMS
Number	Whole number	Demonstrate knowledge of place value, including recognizing and writing numbers in expanded form and representing whole numbers using words, diagrams, or symbols.
		Compare and order whole numbers
		Compute with whole numbers (+, −, ×, ÷) and estimate such computations by approximating the numbers involved.
		Recognize multiples and factors of numbers.
		Solve problems, including those set in real life contexts and those involving measurements, money, and simple proportions
	Fractions & Decimals	Show understanding of fractions by recognizing fractions as parts of unit wholes, parts of a collection, locations on number lines, and by representing fractions using words, numbers, or models.
		Identify equivalent simple fractions; compare and order simple fractions
		Add and subtract simple fractions
		Show understanding of decimal place value including representing decimals using words, numbers, or models
		Add and subtract decimals.
		Solve problems involving simple fractions or decimals
	Number Sentences with Whole Numbers	Find the missing number or operation in a number sentence (e.g., 17 + ■ = 29).
		Model simple situations involving unknowns with expressions or number sentences.
	Patterns & Relationships	Extend or find missing terms in a well-defined pattern, describe relationships between adjacent terms in a sequence and between the sequence number of the term and the term.
		Write or select a rule for a relationship given some pairs of whole numbers satisfying the relationship, and generate pairs of whole numbers following a given rule (e.g., multiply the first number by 3 and add 2 to get the second number).

Geometric Shapes and Measures	Points, Lines, & Angles	Measure and estimate lengths
		Identify and draw parallel and perpendicular lines
		Compare angles by size and draw angles (e.g., a right angle, angles larger or smaller than a right angle).
		Use informal coordinate systems to locate points in a plane.
	Two- and Three-dimensional Shapes	Identify, classify and compare common geometric figures (e.g., classify or compare by shape, size, or properties).
		Recall, describe, and use elementary properties of geometric figures, including line and rotational symmetry.
		Recognize relationships between three-dimensional shapes and their two-dimensional representations.
		Calculate areas and perimeters of squares and rectangles; determine and estimate areas and volumes of geometric figures (e.g., by covering with a given shape or by filling with cubes).
Data Display	Reading & Interpreting	Read scales and data from tables, pictographs, bar graphs, and pie charts.
		Compare information from related data sets (e.g., given data or representations of data on the favorite flavors of ice cream in four or more classes, identify the class with chocolate as the most popular flavor).
		Use information from data displays to answer questions that go beyond directly reading the data displayed (e.g., combine data, perform computations based on the data, make inferences, and draw conclusions).
	Organizing & Representing	Compare and match different representations of the same data.
		Organize and display data using tables, pictographs, and bar graphs.

TIMSS Cognitive Domains

	SUB-AREA	ITEMS
Knowing	Recall	Recall definitions; terminology; number properties; geometric properties; and notation (e.g., $a \times b = ab$, $a + a + a = 3a$).
	Recognize	Recognize mathematical objects, e.g., shapes, numbers, expressions, and quantities. Recognize mathematical entities that are mathematically equivalent (e.g., equivalent familiar fractions, decimals and percents; different orientations of simple geometric figures).
	Compute	Carry out algorithmic procedures for +, −, ×, ÷, or a combination of these with whole numbers, fractions, decimals and integers. Approximate numbers to estimate computations. Carry out routine algebraic procedures.
	Retrieve	Retrieve information from graphs, tables, or other sources; read simple scales.
	Measure	Classify/group objects, shapes, numbers, and expressions according to common properties; make correct decisions about class membership; and order numbers and objects by attributes.
Applying	Select	Select an efficient/appropriate operation, method, or strategy for solving problems where there is a known procedure, algorithm, or method of solution.
	Represent	Display mathematical information and data in diagrams, tables, charts, or graphs, and generate equivalent representations for a given mathematical entity or relationship.
	Model	Generate an appropriate model, such as an equation, geometric figure, or diagram for solving a routine problem.
	Implement	Implement a set of mathematical instructions (e.g., draw shapes and diagrams to given specifications).
	Solve Routine Problems	Solve standard problems similar to those encountered in class. The problems can be in familiar contexts or purely mathematical.
Reasoning	Analyse	Determine, describe, or use relationships between variables or objects in mathematical situations, and make valid inferences from given information.
	Generalise/ Specialize	Extend the domain to which the result of mathematical thinking and problem solving is applicable by restating results in more general and more widely applicable terms.
	Integrate/ Synthesise	Make connections between different elements of knowledge and related representations, and make linkages between related mathematical ideas. Combine mathematical facts, concepts, and procedures to establish results, and combine results to produce a further result.
	Justify	Provide a justification by reference to known mathematical results or properties.
	Solve Non-routine Problems	Solve problems set in mathematical or real life contexts where students are unlikely to have encountered closely similar items, and apply mathematical facts, concepts, and procedures in unfamiliar or complex contexts.

Annex II. Correlation matrix between ELT items

	1	2	3	4	5
1. Recognise most of the letters of the alphabet	1				
2.Read some words	0.705^{***}	1			
3.Read sentences	0.613^{***}	0.823^{***}	1		
4.Write letters of the alphabet	0.678^{***}	0.659^{***}	0.621^{***}	1	
5.Write some words	0.605^{***}	0.725^{***}	0.719^{***}	0.762^{***}	1

Annex III. Descriptive statistics from the control variables

	SEX	PARENT'S HIGHEST LEVEL OF EDUCATION				PARENT'S HIGHEST LEVEL OF OCCUPATION							HOME RESOURCES FOR LEARNING (Average)
	% GIRLS	% PRIMARY EDUCATION	% SECONDARY EDUCATION	% TERTIARY EDUCATION	% NOT APPLICABLE	% PROFESSION AL	% SMALL BUSINESS OWNER	% CLERICAL	% SKILLED WORKER	% GENERAL LABORER	% NEVER WORKED OUTSIDE HOME	% NOT APPLICABLE	
AT	48.75	0.79	73.83	19.62	0.60	24.71	12.70	36.62	10.78	3.61	0.77	2.86	10.43
HR	49.55	0.43	78.53	17.33	0.03	27.86	7.17	36.76	14.00	7.10	1.27	2.02	9.73
CZ	48.07	0.06	73.23	21.80	0.28	34.08	15.45	24.75	16.74	1.28	0.19	3.26	10.51
FI	48.40	0.19	52.62	39.22	0.40	47.41	13.13	23.52	7.77	1.43	0.24	1.37	11.23
DE	45.69	1.14	51.23	20.50	0.28	23.25	9.56	29.60	8.64	1.54	0.48	3.94	10.69
HY	49.02	11.37	54.53	23.57	0.28	24.68	10.24	26.09	12.12	9.54	1.50	5.70	10.05
IE	48.39	3.77	58.38	31.08	0.22	39.02	10.79	20.74	10.95	3.70	1.15	4.25	10.83
IT	49.58	1.81	68.60	17.77	0.25	22.70	12.37	26.75	21.63	2.00	1.35	1.63	9.66
LT	47.25	0.49	62.45	28.38	2.11	26.77	7.25	25.55	14.29	9.07	0.73	7.74	9.84
MT	47.62	2.21	62.94	14.84	0.61	26.61	10.97	21.35	15.41	3.46	1.73	3.79	10.34
PL	48.05	3.23	64.61	29.07	0.20	28.67	13.15	18.87	26.10	2.39	1.77	3.69	9.97
PT	48.71	14.84	54.36	23.78	0.39	29.39	11.21	23.11	16.28	3.06	1.70	5.07	9.89
RO	48.10	10.27	72.08	12.88	0.72	14.42	7.57	21.77	25.54	7.80	12.88	4.78	8.72
SK	49.26	1.26	70.32	24.70	0.10	29.41	13.83	24.27	15.80	2.40	2.78	6.54	9.95
SI	47.33	0.54	72.92	22.54	0.05	37.92	10.00	29.95	11.37	1.66	0.52	2.99	10.42
ES	48.72	5.94	51.82	28.67	0.85	28.50	12.92	23.13	13.48	4.85	1.47	1.66	10.27
SE	47.85	0.99	45.18	34.27	0.18	50.43	9.08	17.61	4.71	1.10	0.57	1.31	11.42
EU	47.93	3.67	59.77	22.96	0.40	26.42	11.25	25.35	15.73	3.18	1.95	3.21	10.13
SNG	48.45	5.83	56.80	31.71	0.39	52.75	10.50	18.78	5.88	1.77	1.04	3.92	10.68

Source: Authors' own elaboration from TIMSS 2011

List of country codes and abbreviations

Country codes

AT - Austria

CZ - Czech Republic

DE - Germany

ES - Spain

FI - Finland

HR - Croatia

HU - Hungary

IE - Ireland

IT - Italy

LT - Lithuania

MT - Malta

PL - Poland

PT - Portugal

RO - Romania

SE - Sweden

SI - Slovenia

SK - Slovakia

SNG - Singapore

UAE - United Arab Emirates

USA – United States of America

EU – European Union

Abbreviations

ECEC – Early Childhood Education and Care

ELT – Early Literacy Tasks

ENT - Early Numeracy Tasks

ISCED - International Standard Classification of Education

MS – Member State(s)

OECD - Organisation for Economic Co-operation and Development

PIRLS - The Progress of International Reading Literacy Study

SES - Socio-economic status

TIMSS - The Trends in International Mathematics and Sciences Study

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