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# Estimation in the Primary Mathematics Curricula of Cyprus, Greece and Turkey: A Privileged or Prevented Competence?

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Estimation is an essential competence with a developmental role in the learning of various mathematical topics. Yet, as previous studies highlight, this competence is either excluded or ambivalently included in intended curricula around the world. The current study investigates the estimation-related opportunities in the primary curricula of three Eastern Mediterranean countries (Cyprus, Greece, and Turkey). Our analyses are framed by four forms of estimation (computational, measurement, quantity, number line). As with previous studies in other contexts, computational estimation and measurement estimation are extensively addressed in the curricula of Cyprus and Turkey, yet without any meaningful justification for their inclusion. All three curricula fail to recognise the importance of number line estimation and quantity estimation, the two forms with the most significant developmental implications for the later learning of other mathematical concepts and areas of mathematics. Among the three curricula under scrutiny, the Greek is the one with the fewest and most superficial references to estimation. In closing, we discuss the implications of this study and suggestions for future research.

*Keywords:* computational estimation, measurement estimation, number line estimation, quantity estimation, intended curricula, Eastern Mediterranean countries

## Introduction

This paper forms part of the activities of an international network of researchers investigating opportunities provided by intended curricula for children to develop estimation-related skills. Estimation, a core skill of everyday life and a major determinant of later arithmetical competence (Sasanguie et al., 2013; Schneider, Grabner, & Paetsch 2009), pervades the lives of both adults and children (Booth & Siegler, 2006). In fact, as argued by Sriraman and Knott (2009, p. 206), estimation is one of "the three most important types of mathematical thinking skills" for primary school children to develop, along with reasoning in ratios and problem solving. Nevertheless, as we contend below, this important skill has received little curricular attention since the introduction of the electronic calculator in the 1970s, with the consequence that much significant research has gone unnoticed and,

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internationally, children's opportunities to acquire estimation-related competence may have been compromised.

As discussed extensively in our network's recent publications (i.e., Andrews, Xenofontos, & Sayers, 2021; Sunde et al., 2021), in the context of mathematics, estimation has historically taken three forms; *computational estimation*, *measurement estimation* and *quantity (or numerosity) estimation* (Sowder, 1992). Today, a fourth form, *number line estimation,* has become a familiar sight in the fields of cognitive psychology, mathematics education and special needs education. All four forms are implicated differently in adults' real world functioning and children's mathematics learning. Drawing on the more extensive accounts of our earlier paper, these four forms of estimation, focusing on their developmental characteristics, are summarised below.

Computational estimation is "the process of simplifying an arithmetic problem using some set of rules or procedures to produce an approximate but satisfactory answer through mental calculation" (LeFevre, Greenham, & Waheed, 1993, p. 95). Other definitions (Dowker, 1992; Siegler & Booth, 2005) equate estimation with approximation as well, which we regard unproblematic. Nonetheless, the definition by LeFevre and her colleagues, which we adopt, explicitly rejects guesswork and highlights the systematic nature of the procedure. Computational estimation is an essential life skill (Ganor-Stern, 2016; Sekeris, Verschaffel, & Luwel, 2019) and, despite teacher scepticism concerning its relevance (Alajmi, 2009), an important facilitator of children's understanding of place value and standard algorithms (Dowker, 2003; Sowder, 1992). It is a strong predictor of general mathematical competence (Seethaler & Fuchs, 2006; Star and Rittle-Johnson, 2009) and correlates positively with measures of mathematics self-concept (Gliner, 1991).

Measurement estimation is defined as measuring without measurement tools involving mental referents to provide a measure of the object under scrutiny (Sowder, 1992). It typically takes three forms (Jones et al., 2012; Joram, Subrahmanyam, & Gelman, 1998):

- *Unit iteration:* iteration of mentally standard units of measure to achieve the desired goal.
- *Reference points*: comparison of the quantity to be estimated against familiar, and therefore meaningful, objects.
- *Decomposition:* splitting the objects of interest into smaller quantities before applying either unit iteration or reference points.

Children of age 9-11 have been found to be poor estimators of lengths, although their estimates improve with age (Desli & Giakoumi, 2017). Middle school children are more accurate estimators when using non-standard rather than standard units (Desli & Giakoumi, 2017). From the perspective of strategies, the most productive strategy seems to be reference points (Desli & Giakumi, 2017; Gooya, Khosroshahi, & Teppo, 2011), not only because children who employ reference points are more accurate than those who do not (Joram et al., 2005) but because the strategy has been linked with mathematics achievement more generally

(Kramer, Bressan, & Grassi, 2018). Moreover, reference points are everyday tools of professional users of mathematics (Jones & Taylor, 2009).

Number line estimation entails “translating a number into a spatial position on a number line” or, less commonly, “translating a spatial position on a number line into a number” (Siegler, Thompson, Opfer, 2009, p. 144). Successful number line estimation draws on an understanding of ordinality (Van’t Noordende et al., 2018) and the use of reference points (Sullivan & Barner, 2014). In many respects, despite having limited real-world relevance, its impact on mathematics learning is profound. It is a predictor of mathematical learning difficulties (Andersson & Östergren, 2012; Wong, Ho, & Tang, 2017), particularly developmental dyscalculia (Huber et al., 2015), and mathematical achievement across all ages of compulsory school (Fuchs et al., 2010; Schneider et al., 2018; Simms et al., 2016; Tosto et al., 2017). In particular, integer line estimation competence has been implicated in children’s arithmetical development across the years of primary education (Dietrich et al., 2016; Friso-van den Bos et al., 2015; Fuchs et al., 2010; Träff, 2013). In similar vein, estimating the position of fractions on the number line is a strong predictor of algebraic readiness (Booth & Newton, 2012) and equation solving competence (Booth, Newton, & Twiss-Garrity, 2014), while decimal number line estimation competence is a better predictor of algebraic competence than either integer or fraction number line estimation (DeWolf, Bassok, & Holyoak, 2015).

Quantity estimation refers to the ability to discern or produce the number of objects in a set without recourse to counting (Crites, 1992). It is a skill reciprocally dependent on the ability to count (Barth, Starr, & Sullivan, 2009) and, irrespective of age, one that diminishes in accuracy as the numerosity of the set of objects grows (Smets, Sasanguie, Szücs, & Reynvoet, 2015). Quantity estimation has been implicated in later arithmetical competence (Bartelet, Vaessen, Blomert, & Ansari, 2014), although other studies have shown that its influence is inextricably tied up with the influence of number line estimation, which, while correlating with each other, independently predict arithmetical competence (Wong, Ho, & Tang, 2016). Recent years have seen scholars turning attention to Fermi problems, problems involving large numbers and expectations that estimations will be accurate to the nearest power of ten, as a means of facilitating students’, across all school years, competence with large numbers (Albarracín & Gorgorió, 2019).

Despite the importance of estimation, its promotion as a whole appears to be educationally problematic. Internationally, estimation is inadequately addressed in textbooks, as found in comparative studies of textbooks’ content in Korea and the United States (Hong, Choi, Runnalls, & Hwang, 2018) and Finland, Singapore and Sweden (Sayers, Petersson, Rosenqvist, & Andrews, 2021). The problem has been exacerbated by the lack of estimation-related expectations in many curricula, including those of the four education systems of the United Kingdom (Andrews, Xenofontos, & Sayers, 2021) and the three education systems of Scandinavia (Sunde et al., 2021). Furthermore, in all constituent nations of the United Kingdom (England, Northern Ireland, Scotland, Wales), as well as Denmark, Norway, and Sweden, more emphasis, albeit limited, is placed on computational and measurement estimation than on number line and quantity estimation. Although the first two forms have explicit real-word implications, free online tools are widely available (i.e., Google Calculator and GPS Fields Area Measure), potentially rendering their related estimation skills redundant. Alternatively, the latter two forms of estimation (number line and quantity) have the most profound developmental implications for the successful learning of other areas of mathematics (Liang, Zhang, Wang, & Liu, 2021; Schneider et al., 2018; Wong, Ho, & Tang, 2016). Simply put, the representation of estimation in current curricula seems to have created a paradox: On the one hand, the two forms of estimation typically privileged in intended curricula – computational and measurement – have many real-life applications that may have been made redundant by the availability of free online tools. On the other hand, the two forms of estimation with the greatest developmental potential – number line and quantity – are effectively absent in the same intended curricula (Andrews, Xenofontos, & Sayers, 2021; Sunde et al., 2021).

In this paper, therefore, we examine the estimation-related expectations of the curricula of the Republic of Cyprus (hereafter Cyprus), Greece, and Turkey. Importantly, in comparison with the earlier studies, what makes this study unique is that it focuses on three Eastern Mediterranean countries with highly centralised educational systems, in which inflexible implementation of prescribed intended curricula has been (Mullis, Martin, Gonzalez, & Chrostowski, 2004; Mullis, Martin, & Foy, 2008) and remains (Mullis et al., 2020) a high priority.

## This Study

The notion of curriculum is complex, multifaceted, and includes much more than prescribed policy documents (Andrews, 2011; Hizli Alkan, 2021; Hizli Alkan & Priestley, 2019; Priestley & Xenofontos, 2020; van den Akker, 2003; Xenofontos, 2019). In fact, Priestley, Alvunger, Philippou, and Soini (2021) use the term 'curriculum making' to highlight these complexities and to indicate that the curriculum is not merely a product, but a process that manifests as social practices at different sites of an educational system. Yet, for the purposes of this paper, we focus on a specific aspect of curriculum, the same way several colleagues describe the *intended curriculum*: a set of formal documents specifying what the relevant regional/national education authorities plan (see, for example, Herbel-Eisenmann, 2007; Hume & Coll, 2010; Porter, Polikoff, & Smithson, 2009; Prendergast & Treacy, 2018).

In the contexts of Cyprus, Greece, and Turkey, the respective educational systems are highly centralised, leaving limited space for teachers to 'deviate' from prescribed agendas. In all three countries, central authorities formulate the intended curriculum in two specific ways. First, they produce national curriculum documents (including, inter alia, guidelines, an overview of mathematical content, benchmarks for specific ages or grades, and sample tasks and activities). Second, they develop national textbooks aimed at reifying the respective curriculum documents. National textbooks are expected to be followed by all state schools in these three countries. In this paper, following the lead of recent analyses of UK

(Andrews, Xenofontos, & Sayers, 2021) and Scandinavian (Sunde et al., 2021) curricula, our attention is turned to the national curriculum documents, and not textbooks.

Our methodological approach could be labelled as *content analysis*. As pointed out by White and Marsh (2006, p. 23), "multiple, nuanced definitions of content analysis exist that reflect its historical development". Nevertheless, for the purposes of this paper, we follow Krippendorff (2004, p. 18), who defines content analysis as "a research technique for making replicable and valid inferences from texts (or other meaningful matter) to the contexts of their use". Table 1 presents the documents included in our analyses. The initial analyses were carried out by Xenofontos (first author), a native speaker of Greek, and Hizli Alkan (second author), a native speaker of Turkish. For each country, the documents were subjected to the same procedure. First, estimation-related keywords and their variants were identified in the documents. Relevant results were copied and pasted into a single text document for each country. In a second round of searches, the occurrences of computation, measurement, number line, and quantity were examined. Third, categorised statements were synthesised into a summary narrative for each form of estimation across the years of each of the three countries' curricula. The section below is based on these country narratives, presented in an alphabetical order. The same analysis approach was recently employed by members of our network in the UK (Andrews, Xenofontos, & Sayers, 2021) and the three Scandinavian countries (Sunde et al., 2021).

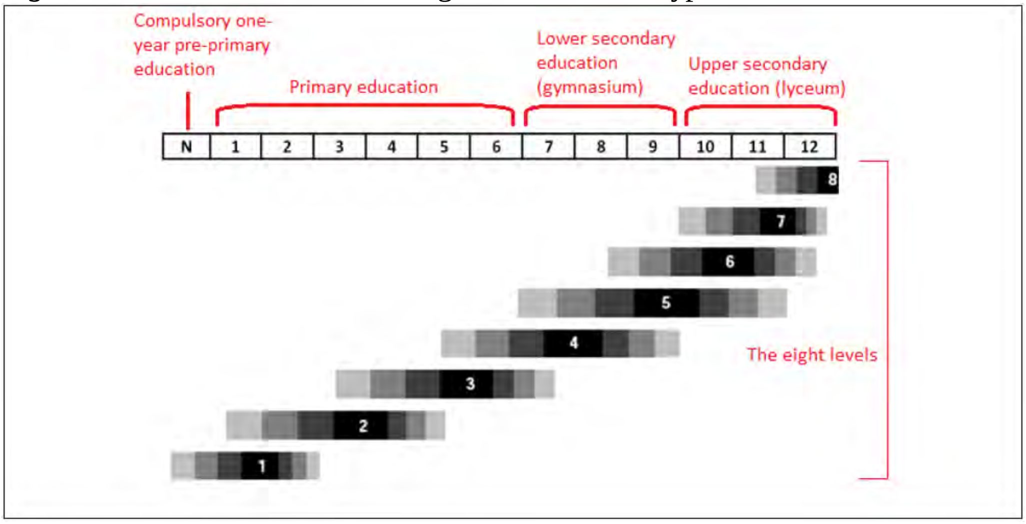
*Table 1.* Curriculum Documents Analysed

| Country | Documents | Keywords (and their variants) |
|---|---|---|
| Cyprus | Ministry of Education and Culture – MoEC (2010b). *The mathematics curriculum* (in Greek). Nicosia: Pedagogical Institute, Ministry of Education and Culture.<br><br>Refined mathematics curriculum for grades 1-6 (MoEC, 2019) http://www.moec.gov.cy/analytika_programmata/programmata_spoudon.html | • Εκτίμηση (estimation)<br>• Στρογγυλοποίηση (rounding)<br>• Κατά προσέγγιση (approximation)<br>• Νοερός υπολογισμός (mental computation)<br>• Αριθμητική γραμμή / αριθμογραμμή (number line) |
| Greece | Ministry of National Education and Religious Affairs – MoNERA (2003). *Cross-thematic curriculum: Government paper 303 & 304/13-3-2003* (in Greek). Athens: Ministry of National Education and Religious Affairs. | |
| Turkey | Ministry of National Education – MoNE (2018). *1-8th grade mathematics education curriculum* (in Turkish). Ankara: Board of Education Publications. | • Tahmin etme (estimation)<br>• Yuvarlama (rounding)<br>• Zihinden işlem (mental computation)<br>• Yaklaşık (approximation)<br>• Sayı doğrusu (number line) |

## The Cypriot Mathematics Curriculum

In 2010, the Ministry of Education and Culture (recently renamed Ministry of Education, Culture, Sports and Youth) of Cyprus launched a new curriculum for public education, for all subjects across school levels, from pre-primary until the end of upper-secondary (MoEC, 2010a; Xenofontos, 2019; Xenofontos & Papadopoulos, 2015). In the initial document for mathematics (MoEC, 2010b), 13 grades of public education are mentioned: one for pre-primary (age 5), six for primary (ages 6-11), three for lower secondary (gymnasium) (ages 12-14), and three for upper-secondary (lyceum) (ages 15-17). The programme is organised in eight levels with overlaps and no clear boundaries regarding which level corresponds to which grade. This happens to emphasise that each pupil understands "mathematical concepts in different ways and pace" (p. 10) and that not all children in the same grade should be expected to grasp all content to the same extent within a single academic year. For each level, benchmarks labelled as "success indexes" are provided. Figure 1, adapted from MoEC (2010b, p. 10), illustrates the relation between the 13 grades and the eight levels. Readers should keep in mind that figures 1-9 illustrate translated parts of the Cypriot curriculum. The original parts are in Greek.

*Figure 1.* The 13 Grades and the Eight Levels in the Cypriot Curriculum




Note: the text in red is our addition, for clarification purposes.

Roughly speaking, levels 1 to 4 refer to primary school, although the main emphasis of level 4 lies in the gymnasium. The fact that no clear instructions are provided concerning which success indexes correspond to which grade (due to the overlaps between the eight levels), concerns have been raised by teachers. These prompted the Ministry to refine the curriculum and produce separate documents for each grade. Currently, on the Cypriot Ministry's website, revised success indexes can be found for both primary (since April 2019) and secondary (since September 2019) mathematics. In the latest documents for each grade, there are clear indications about the corresponding success indexes, as well as some sample classroom activities linked to specific practices, to facilitate the achievement of each index. In terms of content, the curriculum covers the same five areas, from pre-primary until the last year of lyceum: numbers, algebra, geometry, measurements, and statistics/probability.

## Estimation in the Primary Curriculum of Cyprus

In both the extended curriculum (MoEC, 2010b) and the individual curriculum documents for each grade on the Ministry's website, references to estimation and other related terms (i.e., approximation and rounding) appear under two thematic areas: numbers and measurements. Cases where estimation is related to geometric concepts (i.e., area, angles) are presented under measurements, not geometry.

**Computational Estimation.** Computational estimation is one of the two most prevalent types across the primary curriculum. In the extended curriculum document (MoEC, 2010b), relevant examples can be found at all levels corresponding to primary mathematics (levels 1-4). At level 1, for example, pupils should be able to "estimate and calculate the result of mathematical expressions of addition and subtraction up to 20" (p. 19). At level 2, pupils are expected to be able to "estimate the result of a calculation, using strategies of rounding integers to the nearest ten, hundred, or thousand" (p. 31). Similar statements appear for levels 3 and 4. The task in Figure 2 appears under level 3 (p. 55), as an example for teachers in relation to pupils being able to round up numbers in problems.

*Figure 2.* Task from the Cypriot Curriculum

Based on the information in this table, find different combinations of toys Nikos can buy, if he holds €8.00.

| Toys | Price |
|---|---|
| Ball | €2.59 |
| Pair of tennis rackets | €3.83 |
| Puzzle | €1.51 |
| Stickers | €1.02 |
| Set of toy animals | €4.98 |
| Set of toy cars | €5.47 |

While level 4 covers the last years of upper-primary, it is mainly concerned with lower secondary school (gymnasium). At this level, it is stated that pupils should "estimate and calculate the result of mathematical expressions with positive rational numbers" (p. 63) and "negative numbers (integers, decimals, and fractions)" (*ibid*). The following is a word problem presented under level 4 as an example for teachers (p. 73): "Marina bought a computer for €563 and a printer for €329, in 12 monthly instalments. Estimate the amount of each instalment, approximately".

Several references to computational estimation can be found in the 2019 revised curriculum documents for each grade. For example, in the grade 3 document (p. 13), the following sample task is provided: "Estimate the sum of 492 + 286: (a) approximately 600, (b) approximately 7 (*sic*), (c) approximately 800". Similarly, in the grade 4 document (p. 10), the task in Figure 3 is presented.

*Figure 3.* Task from the Cypriot Curriculum

The table below presents the sales of a newspaper for the first three months of its circulation.

| Month | Copies sold |
|---|---|
| September | 14957 |
| October | 21238 |
| November | 9674 |

a. Calculate (*sic*) how many copies approximately were sold during the three months.
b. Calculate (*sic*) how many less copies approximately were sold in November compared to September.

The next example comes from the grade 5 document (p. 14) and is concerned with rounding, a process that falls under computational estimation (Andrews, Xenofontos, & Sayers, 2021): "Tasos rounded a number to the nearest tenth, and the number 635.7 came up. What could be Tasos' initial number, if it had 3 decimal digits?"

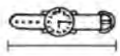
**Measurement Estimation.** Measurement estimation is extensively presented in the curriculum. In the extended curriculum document (MoEC, 2010b), this type of estimation is included in levels from 1 to 3. Under each level, there are examples of tasks that could be used to satisfy the respective success indexes. For level 1 (p. 109), the focus is on length and mass. Pupils are expected to:

- Estimate and measure the length and the mass of objects with standard measurement units (centimetres – cm and kilograms – kg, respectively).
- Estimate and calculate the perimeter of simple 2D shapes with non-standard and standard units (cm).
- Estimate and calculate the area of simple 2D shapes with non-standard units.

In Figure 4 we see a sample task from MoEC (2010b, p. 118).

*Figure 4.* Task from the Cypriot Curriculum

Estimate the length of these objects. Check your answer, using your ruler.

| | ESTIMATE | MEASURE |
|---|---|---|
| Length of my chair's leg  | | |
| Length of a watch  | | |

At level 2, the success indexes become more specific (MoEC, 2010b, p. 124), as pupils are expected to:

- Use different measurement units to estimate and measure the same objects.
- Estimate and calculate the perimeter and the area of squares, rectangles, and right-angle triangles, using appropriate measurement units.
- Use the right angle (90º), to compare, categorise, and estimate angles.

Specific examples of tasks from the curriculum documents for grades 2, 3, and 4, however, refer to exact measurements, not estimations.

At level 3, the success indexes address angles and time (MoEC, 2010b, p. 143). Pupils should:

- Estimate, measure, and categorise angles (with or without using technology).
- Estimate and calculate time intervals for specific events, to the nearest second.

The example in Figure 5 is from the grade 5 document (p. 43).

*Figure 5.* Task from the Cypriot Curriculum

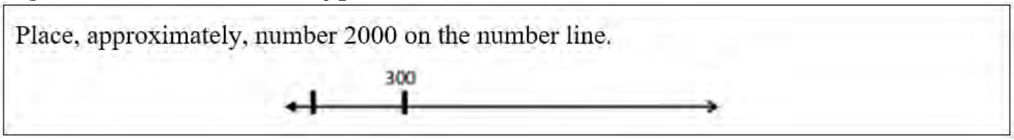
Circle your estimation for each of these angles.

| | | |
|---|---|---|
| A. 68º | A. 175º | A. 108º |
| B. 145º | B. 82º | B. 180º |
| C. 100º | C. 148º | C. 50º |
| D. 20º | D. 25º | D. 87º |

At level 4, there is a single reference to *estimation* (MoEC, 2010b, p. 164), which, however, seems to be erroneous, as the context of that sentence, as well as the sample task presented, alludes to *calculating* areas.

**Number Line Estimation.** The only reference to number line estimation appears in grade 3 curriculum (p. 3), through a suggested sample task, presented in Figure 6.

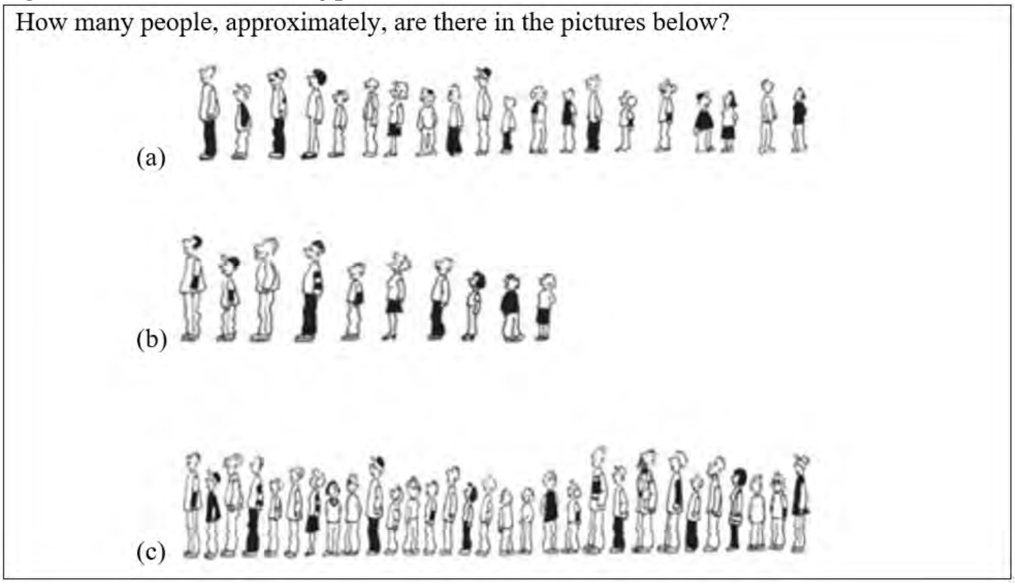
*Figure 6.* Task from the Cypriot Curriculum




Yet, this task appears as an example for a success index that does not refer to estimation at all (*ibid*): "[Pupils should be able to] represent numbers up to 10000, verbally, pictorially, symbolically, and with the use of materials (i.e., Dienes cubes, abaci, number lines, applets)". In addition, the image as it appears in the document represents an impossible task, as the length of the line segment is not long enough for the number 2000 to be placed on it.

**Quantity Estimation.** In the extended curriculum, references to quantity estimation are included under levels 1, 2, and 3. For instance, in level 1 (MoEC, 2010b, p. 19), it is stated that pupils should be in a position to "estimate the cardinality of sets (up to 20)". On a subsequent page (p. 23) the example in Figure 7 is presented.

*Figure 7.* Task from the Cypriot Curriculum




At level 3 (MoEC, 2010b, p. 35), pupils are expected to "[e]stimate the cardinality of sets in activities (*sic*) like:

Estimate and write whether the following quantities are bigger than, smaller than, or equal to 1000.

(a) Pupils of a school
(b) The residents of Lefkosia
(c) All fish in the ocean"

Similar examples are presented in the individual curriculum documents of grades 1 and 2. In grade 4 document (p. 4-5), it is stated that pupils should be able to "use various ways to estimate the cardinality of a set", like "these perceptual strategies: (a) comparison of unknown quantity to a known quantity" (see example in Figure 8), (b) separation of unknown quantity to known quantities" (see example in Figure 9).

*Figure 8.* Example in the Cypriot Curriculum, Illustrating "Comparison of Unknown Quantity to a Known Quantity"


*Figure 9.* Example in the Cypriot Curriculum, Illustrating "Separation of Unknown Quantity to Known Quantities"


In grades 3, 5, and 6 curriculum documents, no reference to quantity estimation is made.

## The Greek Mathematics Curriculum

The mathematics curriculum in effect was introduced in 2003 (MoNERA, 2003). During that year, the compulsory curricula for all school subjects, from preschool to upper secondary (lyceum), were reformed and called "cross-thematic", with the aim of combining the teaching of individual school subjects with knowledge from other subjects (Alahiotis and Karatzia-Stavlioti, 2006). In 2011, following international calls for reinventing curriculum policies and practices (i.e., Priestley & Biesta, 2013), the Greek Ministry designed an alternative curriculum, as part of a reform called the "New School (21st century school)" (MoNERA, 2011). The New School curriculum, which was introduced in some schools in the form of a pilot, was soon abandoned, as it was largely based on the premise that school textbooks should be abolished (Gounari & Grollios, 2012), which is in contrast with the mindsets of many Greek teachers (Xenofontos & Papadopoulos, 2015). Therefore, the only document currently being used is the one produced in 2003, and as such, it was included in the analyses of this paper. For every grade, the curriculum is structured in three columns, corresponding to aims, thematic units (with indicative time to cover each), and sample classroom activities. As far as content is concerned, for grades 1-3 the focus is on three areas: numbers and operations, measurements, and geometry. For grades 4-6, a new content area is added, that of data handling and statistics. For grade 6, two additional areas are included, namely ratios/proportions and equations. Finally, problem solving is presented as a separate content area, relevant to all grades, from 1 to 6.

## Estimation in the Primary Curriculum of Greece

Very few references to estimation and other related terms (i.e., rounding, approximation etc) are included in the Greek primary curriculum. Moreover, these few references are not presented in any consistent manner.

**Computational Estimation.** Computational estimation is briefly presented in grades 5 and 6 only. In both grades, there is a reference to "estimate and check" (MoNERA, 2003, pp. 267 and 272 respectively), but with no further clarifications. In grade 5, pupils should "round natural numbers whenever possible", "check, approximately, the result of an operation", for an "approximating calculation (*sic*) in evaluating the correctness of a result", and be able to perform "mental calculations and approximating estimations (*sic*)" (p. 269). In grade 6, similar statements are repeated, with the addition of rounding "decimal numbers" (p. 273).

**Measurement Estimation.** In the whole primary curriculum, there is a single reference to measurement estimation, whereby grade 1 pupils should "identify and estimate the duration of time intervals" (MoNERA, 2003, p. 256).

**Number Line Estimation.** Most references to number line are not directly linked to estimation. Nevertheless, in some cases, estimation can be inferred. For instance, in grade 2 (MoNERA, 2003, p. 258), pupils should "order natural numbers and use numbers, to identify places on a number line". Similarly, in grade 3, pupils should be able to "use numbers to identify the position of a point on a number line" (p. 261). In grade 5, apart from placing "natural numbers on a number line", pupils should "place one or more natural numbers between two others, when this is possible" (p. 269). Also, in the same grade, pupils should "use decimal numbers to identify positions on a number line" (*ibid*). The only direct reference to number line estimation appears in grade 4, where pupils are expected to "place, approximately, decimal fractions and decimal numbers on a number line" (p. 266).

**Quantity Estimation.** In the whole primary curriculum, there is a single reference to quantity estimation, in which grade 1 pupils should "quickly recognise quantities with structured form of one, two, and three elements (direct estimation)" (MoNERA, 2003, p. 255).

## The Turkish Mathematics Curriculum

The national mathematics curriculum of Turkey was published in 2018 by the Ministry of National Education (MoNE). It is a statutory curriculum covering both primary (grades 1 to 4) and upper-primary levels (grades 5 to 8) (MoNE, 2018). It can be seen as a successor to the major curricular changes between 2005 and 2009, which marked a transition from a behaviourist philosophy of mathematics teaching (e.g., traditional practices focusing on rote memorisation of facts) to constructivist practices (e.g., more focus on conceptual understanding and student-centred pedagogy) (Babadoğan & Olkun, 2006).

The curriculum document outlines generic principles, purposes, perspectives and values of national education in Turkey. Regarding mathematics, there are 13 specific purposes indicated in the curriculum, which include mostly skills (e.g., mathematical literacy skills). For grades 1-4, the curriculum focuses on four content knowledge areas: numbers and operations, geometry, measurement, and data handling. After grade 4, two other areas are introduced: algebra and probability, while geometry and measurement are combined as one content area. Another section in the document is dedicated to generic recommendations about the teaching of mathematics. These points are centred on mathematical reasoning, developing positive attitudes towards mathematics, and using multiple representations. This section is followed by a table outlining each content area/ sub-area and how learning outcomes are distributed through grades, and how much time should be spent in teaching. Although there is some flexibility regarding time allocation and the order of learning outcomes, it is suggested that teachers follow the curriculum (MoNE, 2018).

### Estimation in the Primary Curriculum of Turkey

The Turkish curriculum includes several references to computational estimation and measurement estimation on numbers and operations, measurement, geometry and measurement areas. There is only one reference to quantity estimation on numbers and operations area while number line estimation is not explicitly mentioned at all.

**Computational Estimation.** Computational estimation is referenced extensively across grades 1 to 7. While there are no explicit references in the requirements for grade 1, we infer from the expectation that pupils in grade 1 "should be given opportunities to improve mental computational skills through employing some strategies such as using number bonds and making a 10 can be used in this level" (MoNE, 2018, p. 27) an implicit expectation of estimation. That being said, there are direct references to estimation throughout grades 2 to 7, which become more specific in grades 3, 4 and 5. Following the same content area, number and operations, it is indicated that "pupils can estimate the sum (not over 100) of two-digit numbers and compare the accuracy by checking their answers" (p. 33). Rounding is introduced in grade 3 and is explicitly cited as one of the estimation strategies. A typical statement about rounding is that "pupils round three-digit numbers to the nearest tens or hundreds" (p. 38). In grade 3, pupils are also expected to estimate the sum of two two-digit numbers; one three-digit and one-digit numbers; and, the multiples of 10 and 100 through mental computations. Teachers were encouraged to "place emphases on the affordances of rounding" (p. 60) which is rather a generic statement. The curriculum document presents a few specific strategies later, especially in grade 5. To name a few, "addition by partitioning; adding compatible numbers first; adding or removing zero when multiplying or dividing by 10 or powers of 10; to multiply by 9, first multiply by 10 and subtract the number that it's being multiplied by 9" (MoNE, 2018, pp. 51-52). The totality implies that the statutory expectations depict at least some starting points for unpacking the processes of computational estimation; reformulation, translation and compensation (Reys, Rybolt, Bestgen, & Wyatt, 1982). That being said, these are only explicitly cited in grade 5 with computations with natural numbers, therefore, there is still scope to state potential applications of these to, for example, fractions, decimals and percentages (in grade 6-7-8).

In grade 4, there is an atypical reference to estimation in the section on data handling, where pupils are expected to read bar charts, comment on and make estimations. Such a statement is ambiguous, being interpretable as referring to any one of the four forms of estimation. However, subsequent scrutiny of the relevant authorised textbook showed that pupils were expected to extract data and calculate estimates from them (MoNE, 2018, p. 271). The connection to real life is relatively strong here, as it is in later statements concerning computation with decimals and fractions, where, for example, pupils are expected to "estimate the results of computations with fractions [This should be limited to real life examples including quarters, one thirds, halves]" (MoNE, 2018, p. 60).

**Measurement Estimation.** With the exception of grade 7, there are explicit references to measurement estimation throughout grades 1 to 8. In this respect, the use of non-standard units in both the estimation of measurement and the checking answers to calculations is an expectation beginning in grade 1. For example, pupils are expected to "estimate the length of an object with non-standard units and check the accuracy of their estimation to calculations" (MoNE, 2018, p. 30).

Similar statements, which can be found in subsequent grades, address the concepts of area, mass/weight, capacity and volume besides measurement of length. In grade 3, pupils are expected to "estimate an area with non-standard units and check by counting the units" and "estimate the weight of an object and check the accuracy to measurements" (p.43). Additionally, pupils are expected to "estimate the length of an object that they can directly measure with a most suitable unit and checks its accuracy to calculations" (p.48). Regarding capacity/ volume, pupils are expected to "estimate the capacity of liquid in a cup in litres and millilitres, and measure to check the accuracy" (p.50). There is only one reference to capacity within the commentary on content areas, which states that "pupils compare the capacities of two different cups by using non-standard units" in grade 1 (p.11), with volume being emphasised in grade 6.

The statements about measurement estimation concerning geometrical concepts appear in year 5, when geometry and measurement are combined as a content area. Pupils are expected to "estimate the perimeters of triangles and quadrilaterals and form shapes that have the same perimeter" (p.56). In the same grade, pupils should "estimate the area of a shape in square meters and centimetres" (p.56). Very commonly, the accuracy of the estimation would need to be checked by exact measurements. There is no reference to estimation with respect to time. Measurement of volume is introduced in grade 6, with the curriculum offering a rather enigmatic statement that pupils should "estimate the volume of rectangular prisms" (p. 63).

**Number Line Estimation.** There are references to the number line, involving both standard and non-standard units, as a model for measurement of length but nothing related to estimation. There are references to the placement of different forms of number - fractions, integers, decimals - on number lines. For example, "pupils compare fractions, order them and place on a number line" (MoNE, 2018, p. 59), as well as a solitary reference to pupils being expected to "plot first degree inequalities on a number line" (p. 73). However, any implication with respect to estimation seems incidental rather than planned.

**Quantity Estimation.** There is only one reference to quantity estimation in the curriculum. This states that grade 2 pupils should "estimate the quantity of objects within a set and check by counting" (MoNE, 2018, p. 32) in year 2.

## Discussion

In the previous pages, we summarised the relevant literature regarding four types of estimation, which differ in terms of both form and function. Subsequently, our analyses focused on identifying estimation-related opportunities, provided in the intended primary curricula of three Eastern Mediterranean countries, Cyprus, Greece, and Turkey. Below, we discuss similarities and differences in the ways, and the extent to which, the three curricula promote the development of estimation skills in young children.

In the curricula of Cyprus and Turkey, there is extensive emphasis on computational estimation. For both countries, several strategies are encouraged, along the lines of previous studies (Alajmi, 2009; Boz & Bulut, 2012; LeFevre, Greenham, & Waheed, 1993; Sekeris, Verschaffel, & Luwel, 2019). Yet, this takes place in two different ways: the Cypriot curriculum provides specific examples of tasks through which such strategies are implied, while the Turkish explicitly addresses them, but without providing any examples. Nevertheless, in both sets of documents, the role of computational estimation as an essential life skill (Ganor-Stern, 2016; Sekeris, Verschaffel, & Luwel, 2019) remains implicit. The Greek curriculum offers many fewer references to computational estimation, which appear only in the last two grades of primary school. Overall, all three countries address rounding as a computational estimation strategy. The function of this strategy in computational estimation is often misunderstood by children, who tend to abandon it as they get older (Liu, 2009). Nonetheless, in all three curricula, reflecting the curricula of England, Scotland and Wales (Andrews, Xenofontos, & Sayers, 2021), rounding is generally presented as an end in itself rather than a process related to computational estimation.

There are several references to time-related measurement estimation in the curricula of Cyprus and Turkey, while only one such reference appears in the Greek curriculum. Similar to previous studies (Andrews, Xenofontos, & Sayers, 2021), the common threads across the Cypriot and Turkish curricula included estimation concerning the physical properties of objects such as mass or weight, length and area. Both curricula emphasised the use of non-standard units and then checking answers to exact measurements with the use of standard units, which is known to increase the accuracy of students' estimations (Desli & Giakoumi, 2017). The Cypriot curriculum, however, differs by offering sample tasks related to real life and makes explicit references to mental referents unlike the Turkish curriculum, which offers generic statements. This can potentially inhibit teachers' enactment of the curriculum and students' estimation accuracy and development of number sense (Joram et al., 2005). Only the Cypriot curriculum addresses estimation of angles. The lack of emphasis on this area in the Greek and Turkish curricula may exacerbate already existing uncertainty amongst teachers regarding the teaching of estimation (Joram et al., 2005) and their reluctance to include measurement estimation activities that are not included in national exams (Boz-Yaman & Bulut, 2017). This exemplifies how a lack of clarity and emphasis regarding estimation in the intended curricula alongside high stakes examinations may hinder teachers' curriculum making practices.

Considering previous research about estimation (Andrews, Xenofontos, & Sayers, 2021), it is not surprising, albeit disappointing, to see that number line estimation was not explicitly present in the three curricula. There were a few implicit references, especially in the Greek curriculum, however, these stayed as inferences and were not directly related to estimation. This is an important finding as number line estimation has been shown to predict both mathematical learning difficulties (Andersson & Östergren, 2012) and mathematical achievement in a broad sense (Simms et al., 2016; Tosto et al., 2017). It is also known that number line estimation linked with spatial skills (Olkun, Sari, & Smith, 2019) can be a strong underpinning factor of numerical reasoning (LeFevre, Greenham, & Waheed, 1993).

Quantity estimation, associated with children's ability to count (Barth, Starr, A., & Sullivan, 2009) and a strong predictor of their future arithmetical competence (Bartelet, Vaessen, Blomert, & Ansari, 2014; Wong, Ho, & Tang, 2016) receives limited attention in all three countries' curricula. Specifically, the three countries focus exclusively on younger grades. The Greek and Turkish documents include a single reference each, while in the Cypriot curriculum there are some more elaborate references, with emphasis on real-life examples and two perceptual strategies for children.

## Concluding Thoughts

In conclusion, it appears that the curricula of the three Eastern Mediterranean countries under scrutiny provide limited opportunities for children to develop estimation skills. Specifically, they fail to recognise the importance of number line estimation and quantity estimation, the two types with the greatest developmental implications for the later learning of other mathematical concepts and areas of mathematics (Liang, Zhang, Wang, & Liu, 2021; Schneider et al., 2018; Wong, Ho, & Tang, 2016). This is, in a sense, not surprising. On the contrary, it confirms similar findings by previous studies in other European countries and regions, such as the four constituent nations of the United Kingdom (Andrews, Xenofontos, & Sayers, 2021) and the three Scandinavian countries (Sunde et al., 2021). Put together these findings indicate that pupils around the world may leave school either to continue their studies in higher education or to enter the workforce with poorly developed skills regarding estimation. Although the educational systems of Cyprus, Greece, and Turkey are highly centralised, with teachers having limited discretionary space to 'deviate' from prescribed agendas (Priestley & Xenofontos, 2020) research suggest that teachers often find space to mediate their practice in different ways (Hizli Alkan, 2021; Xenofontos, 2019). Thus, future research could examine how teachers in these three countries construe and reify estimation in their fulfilment of the 'contract' between them and the state. In other words, the ways in which teachers' curriculum making practices are manifested in their unique contexts is worthy of investigation.

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