ESTIMATION SKILLS AND STRATEGIES

Sedef ÇELİK-DEMİRCİ

ORCID ID: 0000-0002-9242-8009

sedefcelik@artvin.edu.tr

Artvin Coruh University

Tuğba BARAN-KAYA

ORCID ID: 0000-0001-9924-4352

tugbabaran@kku.edu.tr

Kirikkale University

1. Introduction

Let's say we have decided to buy a T-shirt. Is this question not the first question that comes to mind when we go to a store or shop online: “Which one of the sizes S, M, L, XL fits me better”? We have a estimate about this question for ourselves. Like this one, thousands of questions run through our minds on a daily basis, and we make up an idea about the approximate value of most of them. We even have an idea of the approximate value of the salt content of the food we eat. Perhaps in a rainy day, we decide either to walk or to get on a vehicle by estimating how wet we can get from the amount of raindrops falling on the ground and the speed of falling to the ground. As you can see, estimating the approximate value of an event during the day also affects our daily decisions. In this context, we can define estimation skill as an individual’s ability to make a quick decision to adapt to daily life easily. Boyraz & Aygün (2017) state that each individual can make predictions, but not all predictions need to be close to the actual value. Therefore, they argue that the concepts of estimation and estimation skill ought be considered as different concepts. In this context, if the concepts of estimation and estimation skill are merged, the estimation skill can be expressed as ‘the competence that enables the individual to produce an estimate close to the real value by performing mental activities without using any tools or equipment’ (Boyraz & Aygün, 2017, p.168). Micklo (1999), on the other hand, defines estimation as knowing the size or quantity of something quickly without the actual counting or measuring process.

In fact, the ability to estimate makes it easier to adapt to daily life and saves us time. For example, the media uses estimates rather than exact amounts, as seen in “150 million pesetas (Spanish currency) for a school population of 63 thousand students” instead of “148,739,426 pesetas for a school population of 62,879”, to make information clearer and more understandable (Segovia & Castro, 2009). Estimation has a critical role in mathematics education as well as in our daily lives (Munakata, 2002). In the past, as it is known, mathematical calculations were made with paper and pencil at length. However, considering that individuals need to make quick and accurate decisions in order to adapt to the skills of the

21st century, the importance of paper-pencil calculations decreases. In this context, pupils are expected to keep up with the current times by making mathematical calculations. Instead of understanding that “Every mathematical problem has only one correct answer”, pupils need to be taught that the answer to a problem can be expressed within the limits closest to the real value (Köse, 2013). The estimation skill, which is intertwined with daily life, play an important role in acquiring many skills such as gaining the sense of number, deciding on the appropriateness of calculation methods, establishing relationships between operations and concepts, etc. (National Council of Mathematics Teachers [NCTM], 2000). Since the use of estimation skills has an important place in daily life, estimation is also included in many mathematics teaching programmes (Australian Education Council [AEC], 1994; Department for Education and Skills [EDCTM], 2005; Ministry of National Education [MoNE], 2005).

In the literature on mathematics education, estimation skills are classified differently. Segovia and Castro (2009) essentially classified the estimation strategy in two different ways, computational and measurement estimation. Segovia and Castro (2009) state that there are two types of sizes in measurement estimation, continuous and discrete, and evaluate numerosity in accordance with this size type. For instance, the case of continuous magnitudes is encountered in how we evaluate someone else’s height compared to our own. Estimating the number of people attending a demonstration is given as an example for the case of different sizes (numerosity). Hogan and Brezinski (2003) classified estimation strategies in three different ways: computational estimation, measurement estimation, and numerosity. Figure 1 shows the classification of estimation strategies. These three estimation strategies differ among themselves in relation to the sub-strategies. For example, Reys et al. (1982) classified the strategies used in computational estimation in three ways: changing the numbers in the process (reformulation), changing the operations (translation) and making arrangements to provide approximation in the result (compensation). On the other hand, Hildreth (1983) dealt with measurement estimation strategies in two ways as clue and foreknowledge. In addition, benchmarking and comparison strategies are widely used in measurement estimation (Joram et al., 2005). On the other hand, while Crites (1992) analyses numerosity, he classified it in three ways such as basic benchmark comparison, decomposition/recomposition, and numerical multiplicity estimation (eye-ball). Figure 1 shows the baseline of the estimation strategy and sub-strategies.

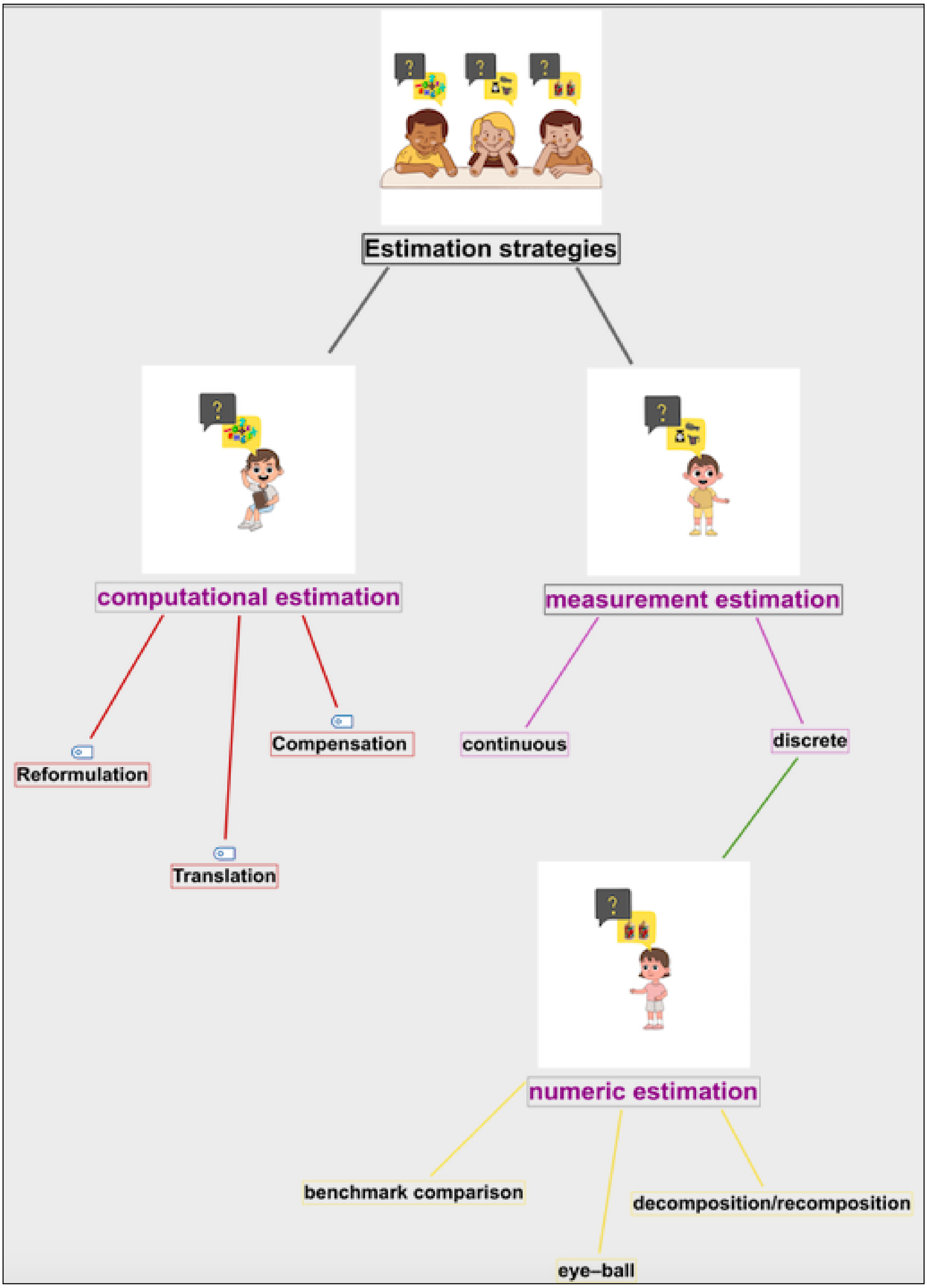

Figure 1. Estimation strategies

2. Computational Estimation

Computational estimation is an invaluable tool for children's daily and academic skills (Case & Sowder, 1990). Wherever there are numbers that are at stake in our daily life, computational estimation is performed there without even thinking about it. For instance, when we take a taxi, we look at the taximeter and give the taxi driver an approximate value of money that we think we may need to pay. For this reason, Dowker (1992) defines computational estimation as the process of giving reasonable and approximate answers to mathematical problems without performing actual calculations. Aslan (2011) defines computational estimation as obtaining a logical result by performing mental operations. Heinrich (1998) also states that computational estimation is a multi-step process that takes place by using the appropriate operations from addition, subtraction, multiplication and division after some mental calculations (rounding etc.). Computational estimation is one of the reasoning techniques because it is based on certain mental procedures (Case & Sowder, 1990). The most general classification of computational estimation is the one that Reys et al. (1982) divided into three as reformulation, translation, and compensation. The characteristics that pupils ought to have in order to be good computational estimators by using these three strategies in computational estimation are summarised below (Figure 2).

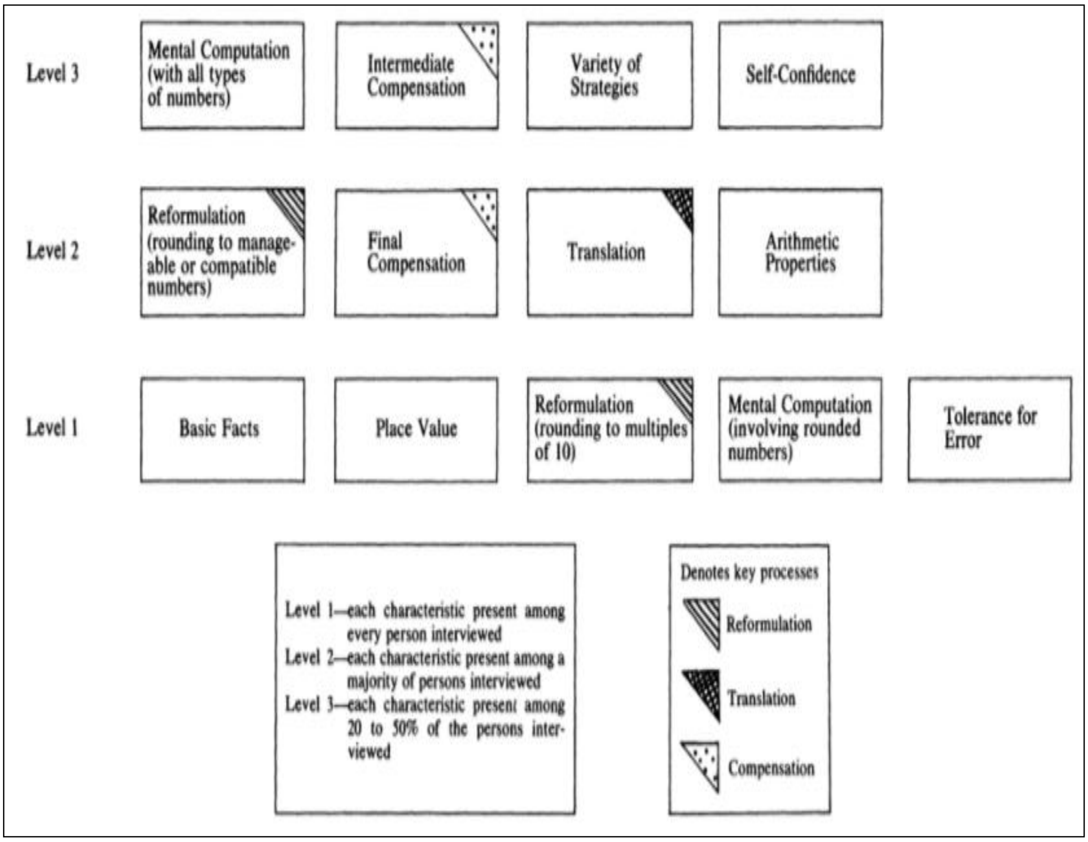

Figure 2. Requirements for a good computational estimator (Reys et al., 1982, p. 197)

As seen in Figure 2, swift and accurate recollection of all operations are essential facts (Basicfacts) to be a good computational estimator. In addition, the understanding of place value is important in determining the correct results of different operations of arithmetic. Also, it is necessary to transform the numerical data in a problem into a mentally manageable format (Reformulation) such as rounding numbers to multiples of 10. Likewise, the rapid and efficient use of mental computation is also important in order to express the estimations with accurate numerical information. It is necessary to consider that some errors can be tolerated in accordance with the meaning and purpose of the estimation (Tolerance for error). It will also facilitate the estimation by allowing adjustments to approximate the result generating from reformulation of the problem. Unlike reformulation, it may also be necessary to change the numbers or change both the numbers and the operations (Translation). While doing these, it is important for pupils to have knowledge of number properties including distribution, association and change, order of operations, and how to use operations (Arithmetic properties). Finally, pupils need to have self-confidence about making the predictions correctly. As can be seen, pupils' self-confidence is as important as considering the margin of error when making computational predictions (Reys et al., 1982).

Many steps are taken in our minds when making computational estimation. When we encounter a problem based on computational prediction from daily life, our mind starts operations with interpreting the data in the problem. From these data, it needs to be decided whether a change will be made about the numbers or about the operations. For example, if the numbers are to be changed, rounding can be performed. For changes related to operations, translations are made on different operations that do not change the result. The mind then tends to check if it undertakes this performance correctly or incorrectly, and makes a series of changes as described in Figure 2. The flow chart in mind, showing how the computational estimation process takes place, is shown in Figure 3.

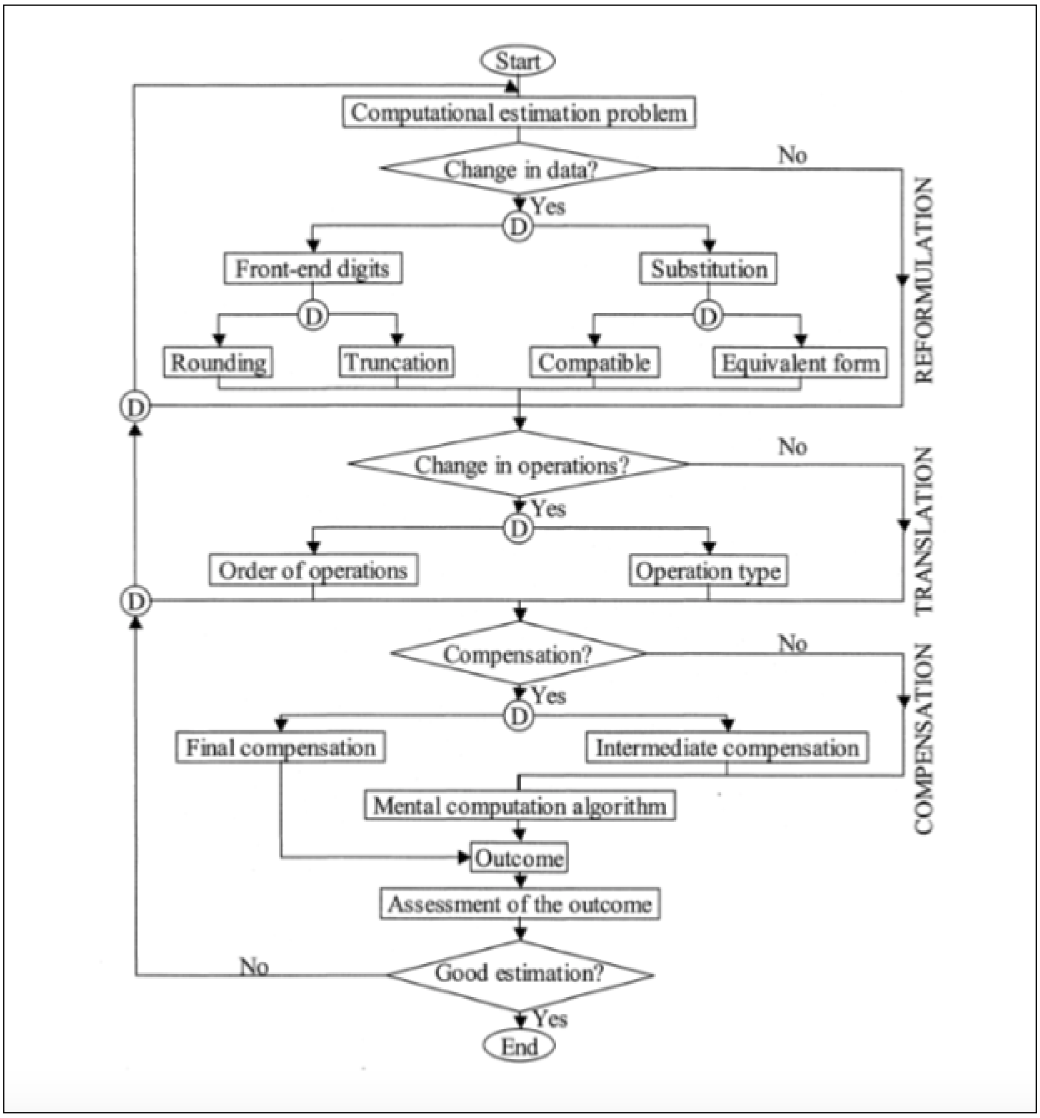

Figure 3. Computational estimation process (Segovia and Castro, 2009, p.534)

Then, how are reformulation, translation, and compensation suggested by Reys et al. (1982) used in computational estimation? How should these mental arrangements be implemented? What strategies enable pupils to sense that they get closer to the result? Can the same strategy be used in every question? Strategies for computational estimation that explain the answers to all these questions are explained below with examples. In the following years, sub-strategies of these strategies were formed and some of them were revised (Çakır, 2019; Tekinkır, 2008; Uygun, 2022).

Numbers Arrangement Strategy

1) Rounding: It is the most commonly used computational estimation skill in the literature (Berry, 1998). Pupils usually round numbers to integers of 10 and 5 to arrive at the result. Levine (1982) examines rounding as Rounding Two Numbers and Rounding One Number. In this case, a number is sometimes rounded to the numbers given in the question; sometimes two numbers can be rounded up.

500+127 = ?: When estimating the result of this operation, the number 127 is rounded to 100. 500 is added to estimate the result as 600. Thus, a number has been rounded.

81x93 = ?: When estimating the result of this operation, the result of the operation is estimated by multiplying the numbers 80 and 93 or by multiplying the numbers 81 and 90. Thus, one of the numbers can be rounded.

5638: 19 = ?: When estimating the result of this operation, it is seen that both numbers are rounded in the estimation of 5640: 20 = 282.

2) Using digits: It is the estimation made by considering the first or last digits of the numbers.

For example, when adding the numbers of 4.6+5.5+6.2+9.8+6.1 = ?, the sum of 4+5+6+9+6 is firstly found. The result found is corrected by working on the digits after the comma. Since the sum of 0.6 and 0.5 is approximately 1; the sum of 0.2 and 0.8 is also 1, by adding 2 to 30, the result of the operation is estimated as 32.

When adding numbers of 4252+6034+7123+5281+3254 = ?, the first digits of the numbers are firstly added: 4+6+7+5+3= 15. Then, considering the possible place value of the result, the result is estimated to be about 15000.

3) Using Number Equivalent/Using matching numbers: It is to prefer more functional numbers by changing numbers. Levine (1982) refers to this change in his strategy definitions as the "known numbers" strategy.

1292.8 + 71.2 by 1300 + 65, which is "known" to be 20.

Regulation-Correction Strategy of Operations

1) Regulation-separation while performing the operation: These undertaken adjustments while performing the operation are in the form of balancing and are related to the identifiable stages of the problem.

In the operation of 79753 + 96421+92843+95609+89821+106409 = ?, numbers other than 79753 are rounded to 100000. 79753 is used to round the others up. In other words, the increase in numbers is offset by excluding 79753. The result is estimated at 600000.

2) Changing the order of operations: It is the execution of operations by changing the places of the numbers without disturbing the equality in order to gain ease and speed while performing the operation.

In the operation of (11/26) + (34/53) + (15/26) = ?, the operation can be undertaken by writing the first and third expression side by side.

3) Regulation-correction made at the end of the operation: It is the regulation-correction made by considering the relationship between the exact answer and the estimation after the calculations are performed. Thus, a certain amount is subtracted from or added to the initial estimate.

In the operation of 82567897/ 43 = ?, if the number 82567897 is rounded to 86000000, the estimated result is approximately 1 000 000. However, the number rounded up need to be estimated to be less than 1 000 000 as it is smaller than the actual number.

5) Distribution strategy: In this strategy, pupils separate the numbers in order to predict the result of the operation.

Whilst estimating the result of the operation of 53x79 = ?, it is estimated by using the distribution feature as (50x79) + (3x79) or (53x70)+(53x9).

6) Strategy of reaching from the part to the whole: It is the strategy in which the operations are divided into steps and sub-sections.

In the operation of 4900: 24 = ?, the number 4900 is approximated by using the multiples of 24 in the process. In this case, 240, 2400 and 4800 are approximated. 200 times 24 equals to 4800. If 4800 is subtracted from 4900, 100 is found. If the number 100 is also divided by the number 24, the result is estimated as approximately 200 + 4 = 204.

7) Grouping: If the numbers in the operation are close to a certain value, the numbers are grouped according to this value and the result is estimated.

Each of the numbers 7123+6997+7040+6985+7289 is close to 7000. If 5 is multiplied by 7000, the result of the operation is estimated as 35000.

Other Strategies

These strategies are also used in other mathematical estimation strategies.

1) Random estimation: Pupils who make a random estimation answer by thinking about the expressions that come to mind randomly and are imagined in their minds.

2) Based on existing knowledge and experience: It is to make estimations based on making use of pre-existing knowledge and experiences. For example, it can be performed by recalling the steps previously used to solve the operation and skipping those steps in the next operation.

A pupil who previously solved the problem of 62x55 = ? uses the result of that operation in order to estimate the operation of 67x50= ?.

3. Measurement Estimation

Measurement estimation is the approximation of the dimensions of objects without using any measurement tool. In our daily life, metres, scales, etc. measurement tools may not always be around us. Estimation options such as “How many apples should I put in the bag when I want to buy 1 kg of apples from the grocery shop?” or “How should I choose my pencil case to hold all of my pencils?” are constantly encountered in our daily lives. In this context, measurement estimation is generally defined as a type of estimation that provides estimates of length, height, weight, liquid capacity and similar samples. For example, it includes estimates such as tool or pen weight, the height of a building, the length of a rope, and the circumference of an area (Hogan & Brezinski, 2003). We use it in our daily life by estimating the size of objects without measuring. In this context, we sometimes make comparisons by taking a reference point. Joram et al., (1998) devised a mental measurement line showing how reference points embody preverbal magnitudes by drawing on Gallistel and Gelman (1992). According to this mental measurement line, nonverbal quantities are indicated by objects and grey columns (Fig. 4). The variability in nonverbal magnitudes is represented by the variation in colour at the top of the grey columns. Written or verbal measurements (figures) are indicated by numbers in quotation marks at the bottom of the graph. The mapping from non-verbal quantities to digits shown on the left is accomplished by dividing the mental number line into segments labelled by measurement (numbers or digits). Figure 4 shows how the size of a concrete object matches numerical expressions.

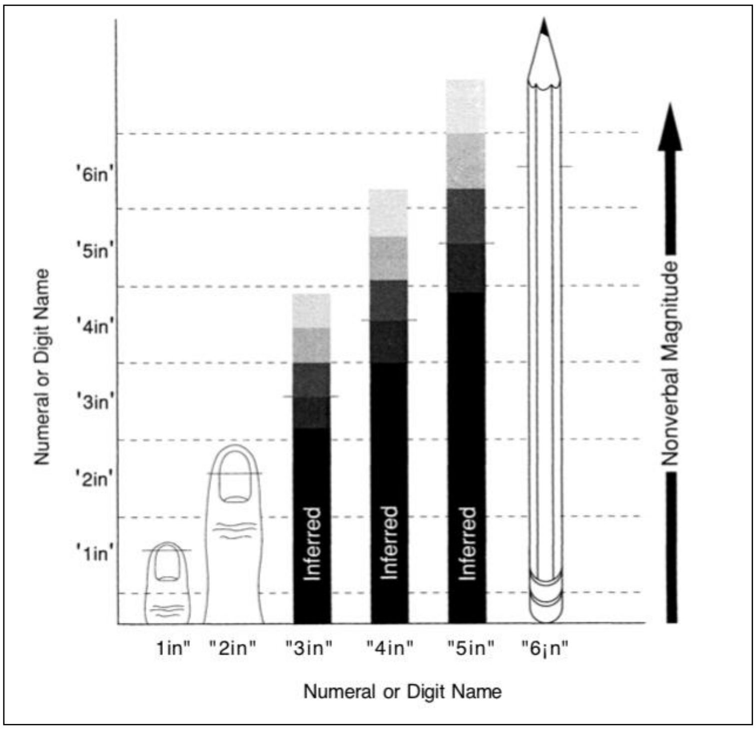

Figure 4. Mental measurement line (Joram et al., 1998, p. 420)

In Figure 4, where the inch unit is used, a numerical expression matches the size of a concrete object, since we learn a bidirectional matching between preverbal magnitudes that represent numeracy and number words when we learn how to count. We use this matching in all areas of numerical proficiency tested verbally. It is known, however, that even though the conceptual foundations for physical measurement and measurement estimation are identical, the processes by which an estimator arrives at an estimate or builds a mental representation of a particular measurement are not the same. In this context, the person measuring with an instrument needs to know certain procedures. For example, the size to be estimated with the ruler is not aligned to be aligned (Gallistel & Gelman, 1992; Joram et al., 1998). Therefore, strategies for measurement estimation need to be well known. Strategies for measurement estimation are described below with examples.

Using references

Compared to pupils who do not use reference points, pupils who use reference points are known to have more accurate representations of standard units and length estimates (Joram et al., 2005). In using reference, an object, item, etc. things can be taken into account as in non-standard units of measurement. For example, tailors estimate how many meters of fabric they will use.

Unit iteration

It is to mentally apply repetitive units and count these units to estimate the length of the object. The ratio of unit size ought to be disaggregated to object size (Hildreth, 1983). Measuring the length of the door with repeated hand movements along the door is an example of this.

Comparison

This is a frequently used strategy for both length and area estimation (Satan, 2020). It is to estimate the object to be measured by comparing it with a unit or reference the measurement of which is known (Tekinkır, 2008). Their length or area is estimated according to whether one is smaller or larger than the other. An example of measurement estimation based on comparison is given below.

The villagers, who see the photos of the plots of their fields from the satellite system, want to have an idea about how many acres the fields will be before they receive the title deeds. It is known that the small plot belongs to the governor of the village and it has been determined that this place is 4000 m2. According to that, the large plot adjacent to the governor's is m2.	 Source: https://parselsorgu.tkgm.gov.tr/#ara/idari/162497/247/5/1667600341549

Visualisation

It is to estimate the object that is to be estimated by visualising it and comparing it to another object, the measurement of which is known (Siegel et al., 1982). In this strategy, which is especially used in measurement estimation, pupils made an estimation based on how long a ruler of 1 meter or 30 centimetres ought to be (Çilingir and Türnüklü, 2009).

Estimating based on existing knowledge and experience (Prior knowledge - using information)

It is to estimate by making use of prior knowledge and previous experiences, akin to computational estimation. For example, when parking between two vehicles, we use this type of estimation by recalling our previous parking knowledge in the process of deciding whether our vehicle will fit between two vehicles.

Compression (Squeezing)

It is an estimation strategy made by reducing the measurement result to a set of values (Hildreth, 1983). For example, when estimating the length of a stovepipe, it is to estimate as in more than 1 meter and less than 2 meters.

Reaching the whole from the part

The problem is divided into sub-problems and the answers obtained from these sub-problems are combined and the result of the whole is estimated (Aslan, 2011). For example, considering the numbers of tiles required to lay the floor of a bathroom, how many tiles are needed for all walls are estimated.

Using subdivisions/ Fragmentation

It involves making an estimation by decomposing or dividing the object to be measured into sub-units (Siegel et al., 1982). Unlike the part-to-whole strategy, it is used to measure objects that do not consist of parts (Uygun, 2022). For example, it is to estimate the distance between two provinces by dividing the distance between two provinces according to the distances between the districts on the road route.

Random estimation

It involves estimating randomly without using any logical process and strategy. For example, when estimating the length of the table, it is a random estimation to say 2 m without relying on any logic.

Estimating by experiment

It includes other estimation skills (Çilingir and Türnüklü, 2009).

4. Numerosity Estimation

How many words do you think this book you hold in your hand consists of? The first answer we give to this question is without counting the words one by one, isn’t it? In our daily life, we are often faced with such questions. For example, when a teacher enters the classroom, they can estimate how many people are in the classroom without taking attendance. As can be seen, the answers to the question of "how many" for the number of objects in any area are the main concerns of numerosity. So, how can we find the approximate value of a large group of objects without counting them one by one? In other words, how can we do the numerosity? As seen in computational and measurement estimation strategies, there can be found sub-strategies of numerosity in the literature. Crites (1992) made the most basic classification of the numerosity strategy by dividing it into three as benchmark comparison, decomposition/recomposition, and eye-ball. The numerosity strategies are described below, along with examples.

Benchmark comparison

It is an estimation by comparing the baseline measure. For example, imagine that pupils are asked a question about how many beans a jar will hold. Numerosity estimation is the pupils' guesses that they make by comparing the popcorn kernels and bean kernels in the other jar of the same size. Thinking that the bean kernels are larger than the popcorn kernels, they estimate approximately how many beans the jar will hold. A base size comparison can also give an idea of the length of an object. It is possible to have an idea about the whole object by starting from a unit. For example, a link is approximately 1 inch long and there are 36 inches in 3 feet. In this context, the baseline measure comparison is based on the numbering of many points by visually comparing objects. Based on the initial numbering made visually, the remaining points are estimated and added to the numbered result. Below is an example where a baseline measure comparison can be used.

An approximation of the number of other books in a bookcase by counting the books on the top shelf in a bookcase. Finding the total number of books in the library by adding the number of books on the next shelf to the number of books we count first.	 Source: https://www.evrensel.net/haber/381882/dersimde-kutuphane-ve-muze-kuruluyor

Decomposition/recomposition

It is the estimation of the total multiplicity by making an estimation about a part or small subgroup of a group of objects in a community. Fragmentation or subgrouping ought to be intended to give an idea of the large group to be estimated. For example, to estimate how many dots are used in the text, first estimate the number of points used in the whole text by counting the dots in a line.

Eye-ball (numerical multiplicity)

In the numerical multiplicity estimation strategy, visual scanning and heuristic perception are at the forefront. For example, the use of expressions such as "it seems" to estimate the popcorn in a jar is an example of heuristic perception. With the numerical multiplicity estimation strategy, we can make quick and accurate decisions by counting larger numerical multiplicities by grouping them. Below is an example where the numerical multiplicity estimation strategy can be used.

How many salmons are produced daily in a salmon farm? To answer the question, we first need to estimate the number of fish in a pond. By grouping the number of fish in the pond, we can make an estimate of the great multiplicity.	 Source: https://www.ntv.com.tr/galeri/ekonomi/borcka-barajindan-dunyaya-somon,XHM_q6f_Qk6CBfjukyuAVA/xgyN-RQIVk6izLf9OS60Xg

5. Conclusion

The estimation strategy is a reasoning technique that we use constantly in daily life, either consciously or unconsciously. The individual decides on their own which estimation strategy to use in an event in daily life. The estimation strategy shown in the examples given to computational, measurement, and numerosity can vary from person to person as the cognitive schemes in each individual's mind are different. Also, in a daily life situation, more than one estimation strategy can occasionally be used. When estimating in the real sense, a rote-based approach is avoided and one draws from their own mathematical insights. In addition, there may be different estimation strategies other than the estimation strategies listed above. Uncovering these strategies in mathematics classrooms is of great importance.

Examining computational estimation as one of the estimation strategies, examples of computational estimation need not be merely computational. Numbers must have a value in daily life. Only then, the pupil will be mentally active, acknowledging the value of calculating and estimating. When examining the measurement estimation, it is understood that estimation strategies differ within themselves. For example, a baseline measure comparison can be in the form of comparing both different objects and the units within the object itself. On the other hand, if there is a transition from non-standard measurement units to standard measurement units, pupils are supported to easily employ strategies such as unit repetition, etc. If the transition in mathematics curricula is presented as such, pupils' estimation skills can improve. Another important issue in mathematics curricula is that very little attention is given to the teaching of numerosity. In this regard, activities in which pupils can use different estimation strategies need to be included in mathematics courses. In fact, with the help of such activities, random estimators can gradually start using strategies such as use of reference points and comparison.

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