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Investigation of the computational estimation skills of and strategies employed by pre-service primary school teacher

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ABSTRACT

This study intends to review the operational estimation skills of pre-service primary school teachers, and to see if they are able to use the correct strategy when making estimates. For this purpose, the "estimation skills test" comprised of 41 questions allowing estimates using 14 distinct estimation strategies was used. 209 pre-service primary school teachers took part in the study. The responses provided by the pre-service teachers were scored on the basis of the accuracy of the estimation. Furthermore, the responses to the questions in the test were scored with reference to the applicability of the estimation method, on a binary scale of 0 and 1. The study revealed that the pre-service primary school teachers had mediocre operational estimation skills, and that majority of them failed to use the optimal strategy. In this context, one should recommend the offering of undergraduate courses to pre-service primary school teachers to improve their estimation skills.

Keywords: mathematics education, computational estimation skills, pre-service primary school teachers, teacher education

INTRODUCTION

In daily life, individuals frequently face circumstances requiring operational estimation skills, and feel the need to estimate the result through reasoning. Yet, due emphasis on efforts and practices to enhance the estimation skills of the students were lacking in Turkish schools, till 2004, with MEB's (Ministry of Education) refresh of curricula for primary school courses. Even though the objectives of the previous mathematics curriculum had references to estimation skills, it is well known that classroom practices fell short of being effective (Cilingir & Turnuklu, 2009). The mathematics curriculum that was introduced as of the academic year 2004-2005 includes improvements regarding estimations and quick calculations, coupled with specific estimation strategies (MEB, 2005). The preamble of the curriculum states that, given the ever changing modes of engaging in mathematics and communication thanks to new pieces of knowledge and technologies, the importance of calculations using pen and paper was falling, while skills such as estimation and problem solving were gaining ascendancy (MEB, 2009). Developing the student's estimation skills is also among the special purposes of the mathematics course curriculum published in 2018 (MEB, 2018). Now, the overall objectives of mathematics education in Turkey includes enabling primary school graduates "to use estimation and mental computation skills effectively". In line with this objective, gains with a view to enhancing the estimation skills of the students from the first year on are now made crucial elements of the mathematics curriculum.

The natural question to follow is "What is estimation?", "Why is it so important?", and "Which kinds of strategies can be applied for estimations?" Turkish dictionary defines estimate as "approximate assessment, guess" (TDK, 2020). According to Micklo (1999), estimation is about coming up with a quick assessment of something's size or quantity, without an actual count or measurement (quoted in Tekinkir, 2008). Estimation is a process of producing answers that are close enough to allow for good decisions without performing elaborate or exact computations (Reys et al., 2009). In other words, estimation is a method employed frequently in daily life, whenever it is not possible or feasible to get the exact answer (Rubenstein, 1986), or where an approximate answer would do. Van de Walle (1994) notes four distinct types of computation in real life: pencil and paper based computation, estimation, mental computation, and calculator- or computer-assisted computation. Oftentimes mental computation is confused with estimation. Reys (1986) defines mental computation as reaching to the exact answer without using any calculation aids. The mental computation aims to find the exact answer, while estimation seeks to find a good-enough approximate result. For instance, quick estimations are required to respond to questions such as "approximately how much would I pay if I bought four of the sweaters which cost 38 liras each?", "should I buy two for the price of one at 27 liras", or "should I get 50% discount in pizzas costing 32 liras?". Yet, naturally, mental computation is employed for such estimations (Reys, 1985).

Today, technological developments enable us to get exact results fairly easily, while we still have to rely on human mind to assess the logicality and applicability of the results reached thus (Boz & Bulut, 2012). Recent studies reveal that specialists such as scientists, engineers, or mathematicians employ estimation before actually using assessment tools to reach to exact results (Jones & Taylor, 2009; Jones et al., 2012). Educators who emphasize the importance of estimation skills (Brade, 2003; Desli & Lioliou; Reys, 1984; Reys & Bestgen, 1981; Reys et al., 1991; Sowder & Wheeler, 1989; Van den Heuvel-Panhuizen, 2001) note that it is a skill required not only for a few occupations and daily life, but also helps develop numerous mathematical skills, such as mental activities, spatial visualization, assessments, and understanding quantities (Kose, 2013). That is why it is imperative and necessary to instill skills such as reasoning, interpreting, mental calculus, creative thinking, and estimation in the students, from their earliest years on.

A review of the literature on estimations reveals that some researchers distinguish assessment- (measurement-) based and computational estimations (Aytekin, 2012; Cilingir & Turnuklu, 2009; Segovia & Castro, 2009), while some others employ a classification based on numerosity, measurement, and computation (Hanson & Hogan, 2000; Hogan & Brezinski, 2003; Munakata, 2002; Siegler & Booth, 2004; Siegler & Opfer, 2003; Sowder, 1992; Tekinkir, 2008).

Numerosity estimation is employed to determine the quantity of the objects or points within an arrangement, where exact computation is not possible or necessary (Hogan & Brezinski, 2003). Examples could include estimating the numbers attending a pop concert, the pairs of shoes in a shoe store, or the number of oranges in a box.

Measurement estimation refers to reaching an assessment concerning a length, weight, time, volume, etc. (Hogan & Brezinski, 2003). It is arguably the most common type of estimation employed in daily life. For instance, the estimation of the amount of time a vehicle moving at a speed of 70 km/s would cover a distance of 20 km, or of the height of a building, the distance between home and school, or the approximate weight of the bags a customer carries out of a market are all examples of measurement estimation.

Computational estimation refers to the approximate results reached without using formulaic processes and calculations in operations (such as 328+719, 4269÷22, or 0.19×1.87) (Dowker, 1992; Hogan & Brezinski, 2003). Sowder (1992) defines computational estimation as getting results in a certain range, close to the actual result, by employing certain cruder operations mentally. Computational estimation is considered a crucial mathematical skill; its importance is emphasized in numerous studies concerning fundamental mathematics skills (Reys et al., 1982). The importance of this skill becomes evident in the light of the fact that it would be impossible to have a calculator or pen and paper around to solve any problem we come across in our daily lives. For instance, upon learning that the product we intend to buy is discounted at a rate of 50%+30%, calculating the final price, as well as the change we would get in the end requires us to make computational estimations.

One can employ a number of estimation strategies in various settings, and come up with a wide range of strategies for each estimation type. Estimation strategies are clearly not universally applicable. The literature is not poor in studies about the strategies employed by individuals, and the processes they apply to effect estimates, discussing some strategies in detail. Some scholars came up with their own categorizations of these strategies. According to Crites (1992), numerosity estimations are carried out by using the strategies such as "benchmark comparison", "decomposition/recomposition", and "eye-ball". Measurement strategies also had their share of classification in the literature (Gooya et al., 2011; Hildreth, 1983; Joram et al., 1998; Kilic & Olkun, 2013; Luwel & Verschaffel, 2008; MEB, 2009; Segovia & Castro, 2009; Tekinkir, 2008; Van de Walle, 2004). "Estimation based on existing knowledge and experience", "visualization"; "chunking"; "comparison"; "random guess"; "experimentation"; "using an anchor or reference"; "unit recursion"; "squeezing" are some of the strategies which received specific mention in the literature.

Theoretical Framework

Computational estimation strategies

In the literature, computational estimation strategies are generally categorized under three groups (Heinrich, 1998). These are "reformulation", "translation", and "compensation" (Reys, 1984; Reys et al., 1982). This study analyses 14 sub-groups of strategies under these three primary computational strategy categories (Levine, 1982; Sulak, 2008):

A. Reformulation

A.1. Digit-based formulation

A.1.a. Using the first digits: This strategy entails the computation of a crude result by adding the first digit or first two digits of the numbers in question.

e.g.: 81,419+92,765+90,045+81,974+98,102=?

Solution: The computation is applied by ignoring all but the first digits of the numbers in question. 8+9+9+8+9=43 gives a crude result, which suggests that the result of the actual calculation would be near 430,000.

A.1.b. Rounding to the nearest multiple of 5, 10, or 100: This strategy is based on rounding the numbers at hand to the nearest multiple of 5, 10, or 100 with a view to making computation easier.

e.g.: 584,267/6,298=?

Solution: In this operation, the number 584,267 is rounded up to the nearest grand-multiple of 100, which is 600000, while 6,298 is rounded down to the nearest grand-multiple of 100, which is 6,000. Then, the operation can be completed on the basis of this simpler configuration, producing an approximate result of 100 as the result of 600,000/6,000.

A.2. Compatible numbers

A.2.a. Using compatible numbers: This strategy is about choosing the numbers which are easier to operate with among themselves.

e.g.: 347x7/47=?

Solution: In this operation 7 and 47 arise as the compatible numbers. 47 would be rounded up to 49, enabling abbreviation with 7. 347 would, in turn, be rounded up to 350. Once the operation is converted to the 350x7/49 form, the result can be estimated as 50.

A.2.b. Using equivalent numbers: This strategy entails the replacement of a given number with an equivalent (decimal or fraction) before performing the operation.

e.g.: 7,858/51=?

Solution: In this operation the number 51 can be replaced with 1,002. 7,858, in turn, would be rounded up to7,800, producing the operation 7,800x2/100 leading to the estimate of 156.

A.3. Rounding strategy

A.3.a. Rounding one number: In this strategy, just one of the numbers involved would be rounded to perform the operation.

e.g.: 93x18=?

Solution: Before proceeding with the operation 18 would be rounded up to 20, leading to an operation of 93x20 to produce the estimate of 1,860.

A.3.b. Rounding both numbers: In this strategy, both numbers involved would be rounded to perform the operation.

e.g.: 142x37=?

Solution: Both numbers in this operation are difficult to handle in mental computation. That is why, they are rounded to more convenient figures before performing the operation. Once the numbers are rounded, the estimation would be performed on the basis of 140x35, 145x40, 140x40, or 145x30.

A.3.c. Multi-step rounding: This strategy refers to the performance of the operation where usually fractions are rounded to special values such as 0, 0.5, or 1.

e.g.: 12/13+6/8+1/17=?

Solution: Given the difficulty of producing matching denominators to carry out the operation, the fractions would be reviewed in terms of their proximity to 0, 1 or 0.5. 12/13 is close to 1, 6/8 is close to 0.5, and 1/17 is close to 0. 12/13+6/8+1/17=? The result can be estimated as 0+0.5+1=1.5.

A.4. Estimation with exponential formulation: In this strategy, the numbers involved would be represented as a power of a component thereof, or of 10 before performing the operation.

e.g.: 0.47x0.26=?

Solution: In this operation, 0.47 would be represented as 5x10-1, while 0.26 would be represented as 3x10-1, producing a result of 15x10-2, which would then be translated to the form 0.15.

B. Translation

B.1. Rearranging operations: This strategy entails the application of the operation after rearranging their order so as to produce mathematically equivalent results.

e.g.: 2314-815+1743=?

Solution: In this operation, 815 is easier to subtract from the result produced through the addition of 2,314 and 1,743. Therefore, the individual operations would be reordered to produce the operation of (2,314+1,743)-815, enabling the estimation of (2,300+1,700)-800=3,200.

B.2. Grouping: This strategy is based on the proximity of the numbers involved to a given figure, which would be used as the basis of further grouping before actual operation. The goal, in this context, is to use the associativity of addition.

e.g.: 723+704+789+726+771+757+730=?

Solution: Before proceeding with the operation, given the proximity of the numbers involved, to 700, the operation would be converted to 7x700, to produce the estimate of 4,900.

B.3. Decomposition: This strategy refers to the decomposition of multiplication to addition or subtraction.

e.g.: 95x28=?

Solution: Once the operation is transformed to (100x30)-(100x2), the result can be estimated through the operation 3,000-200.

B.4. Factorization: This strategy is effectively based on the factorization of the number, or abbreviation with a common divisor.

e.g.: 12.6x11.4=?

Solution: In this operation, a frequently applied factorization rule, (a+b)x(a-b)=a2-b2, is employed, to transform the operation into the form (12+0.6)x(12-0.6)=122x0.62 leading to an estimation of 144-0.36=143.4.

B.5. Missing operational sections: This strategy entails the decomposition of the existing numbers into elements thereof, which would, when summed up, produce the original number, with a view to combining the interim numbers to produce a simpler operation.

e.g.: 486x1/4=?

Solution: In this instance, once the numbers are decomposed into easier to operate elements, the operation would be transformed into the (400x1/4)+(86x1/4) form. Later on, the number 86 would be rounded up to 88, to make it easier to divide by 4. The result can be estimated as 100+22=122.

C. Compensation: This group of strategies try to make the estimation result a better approximation of the actual result, through computational and operational adjustments.

C.1. Intermediate compensation: This strategy is based on ignoring, in the beginning of the operation, the numbers or operations which would make calculation difficult or time-consuming.

e.g.: 58,274+64,392+62,105+52,948-29,843=?

Solution: All the numbers in this operation, but 29,843, can be rounded to 60,000, while 29,843 is not even close to 60,000. Therefore, it cannot be rounded to this figure, and makes the operation difficult. That is why this number is ignored in the beginning of the operation, while other numbers are grouped around, or rounded to 60,000, leading to an estimation of 240,000.

C.2. Final compensation: This strategy is all about a review of the application of the operation once the mental computation is completed.

e.g.: 3,134x23=?

Solution: The result of the operation transformed into the form 3,134x23=(3,100+34)x(20+3) can be estimated as 3,100x20=62,000. Yet, this model of operation involves a substantial error margin (3,100x3)+(34x23). 3,100 is rounded to 3000, to effect the operation 3,000x3=9,000; 34 is rounded to 30, and 23 is rounded to 20, to effect the operation 30x20=600, leading to the addition of these figures to the existing estimation, to produce the final estimate of 62,000+9,000+600=71,600.

Cilingir and Turnuklu's (2009) piece published in 2009 argues that the estimation studies focus on these three areas. In this perspective, the focus is on the relationship between estimations and other skills (Bestgen et al., 1980; Levine, 1982; Rubenstein, 1985); comparison of the methods of estimation education (Bestgen et al., 1980), description of the strategies employed by people with good estimation skills (Reys et al., 1982), and the identification of the strategies employed by people with poor estimation skills (Sowder, 1984). The review of the literature in Turkey reveals a wealth of studies on estimation skills (Aslan, 2011; Aytekin, 2012; Köse, 2013; Soylu, 2008), or the estimation's impact on education, or the strategies employed for estimations (Boz & Bulut, 2012; Cilingir & Turnuklu, 2009; Kilic & Olkun, 2013; Sulak, 2008; Tekinkir, 2008). Yet, studies to identify the estimation strategies employed by the teachers and pre-service teachers (Sulak, 2008) are almost non-existent. In this context, there is definitely room for scientific studies to assess whether pre-service primary school teachers, who are expected to instill in children the skills to understand and use mathematics in daily life, apply appropriate strategies for operations requiring estimation skills, and therefore to reveal the impact of the undergraduate education they receive, on the development of estimation skills.

Purpose and Research Questions

This study aims to reveal the computational estimation skills of pre-service primary school teachers. In line with this objective, the following problems are investigated, with a view to identify the 4-year university studies pre-service teachers have, on their levels of computational estimation skills. For the purpose of this study, the following questions were answered in the study.

The study focuses on three distinct research problems:

1. How do the computational estimation skill levels of pre-service primary school teachers vary with reference to the year of education in the program? Is there a statistically significant relationship between their skill levels and the year of education?
2. How do the applicability of the strategies employed by pre-service primary school teachers when engaging in operations requiring estimation skills vary with reference to the year of education in the program? Is there a statistically significant relationship between the use of applicable strategies and the year of education?
3. Is there a significant relationship between the computational estimation skill levels of and the applicability of the strategies employed by pre-service primary school teachers?

RESEARCH MODEL

Design

Research problem is partly about the establishment of the applicability of the strategies employed by as well as the computational estimation skills of pre-service teachers at the 1st, 2nd, 3rd, and 4th year of their studies. In the light of this problem formulation, qualitative research approach was adopted, in the form of the developmental research method. The objective of developmental research is to reveal the change occurring with the individuals, investigating the questions such as "how was it before", "how did it change" (Kilic & Cinoglu, 2008). Developmental research can be longitudinal, as well as cross-sectional (Miller, 1998). A cross-sectional study involves observations of a sample, or cross section, of a population or phenomenon that are made at one point in time (Babbie, 2013, p. 105). Cross-sectional research tries to shed light on the research question through simultaneous observations on distinct groups assumed to represent various levels of development. This approach enables the interpretation of the results as if they pertain to a single group, on the basis of the assumption that development is characterized by continuity (Karasar, 2011, p. 80). The present study also employs that assumption, and has adopted a cross-sectional approach. Another part of the research problem is an investigation of whether the applicability of the computational estimation strategies and estimation skill levels of pre-service teachers significantly vary with reference to their year of education, or not. Furthermore, the estimation skill levels of and applicable strategy use by pre-service primary school teachers should be reviewed with reference to the class level variable. Against this background, quantitative research approach was found to be more feasible, leading to the use of the survey method to establish the relationship between various variables and the estimation skills of pre-service teachers.

Participants

The study focuses on all pre-service teachers receiving education at the primary school teacher education department of the faculty of education at an established university located to the north of Turkey. The study universe thus set is represented by a sample of students from a classes of each year of the education program, chosen on the basis of stratified random sampling. Primary school teachers in Turkey are trained through a four-year undergraduate program. Pre-service teachers from all years of this process were enrolled in the study. 44 pre-service teachers from the 1st year, 47 from the 2nd, 59 from the 3rd, and 49 from the 4th were included in the study, amounting to a total study group size of 209.

Data Gathering Tools

The data gathering tool employed in the study were "personal information form" and the "computational etimation skill test". The personal information form is drawn up to request information on the year, ages, gender, high-school type, and university admission exam score. The computational estimation skill test, on the other hand, is developed by Sulak (2008) to assess the estimation strategies of pre-service teachers, to provide input to a graduate dissertation. The researcher calculated Cronbach's alpha reliability factor to test the reliability of the scale, and found 0.74. The test entails questions requiring the use of a total of 14 estimation strategies under three basic strategy groups. These basic strategies are reformulation, translation, and compensation (Sulak, 2008).

Reformulation refers to a group of strategies including the use of first digits, rounding to multiples of 5, 10, or 100, use of compatible or equivalent numbers, rounding, multi-step rounding, and use of exponential formulation. *Translation* refers to a group of strategies including the rearrangement of the operations, grouping, decomposition, factorization, and missing operational sections. *Compensation* refers to a group of strategies including the compensation in the beginning of the operation, and compensation at the end of the operation. Each specific strategy (save for one) were represented in the scale with three questions, while the "compensation in the beginning of the operation" was represented with two, adding up to a total of 41 questions.

Data Gathering

The scale was applied during an available class of the pre-service primary school teachers. The pre-service teachers were asked to estimate the results of the operations in the scale, within a time frame of approximately 45-50 minutes. They were also expected to affect the estimation procedures on paper, so as to provide insights into the estimation strategies they employ. The scale was applied in an environment isolating pre-service teachers from each other's influence.

Data Analysis

The responses provided by the pre-service teachers in the computational estimation skills test were reviewed in light of the scoring systems proposed by a number of researchers (Levine, 1982; Sulak, 2008). The responses provided to the test were analyzed twice. First of all, the estimates provided by pre-service primary school teachers were analyzed in terms of accuracy, followed by a further analysis of applicability of the strategies employed for the estimates.

Each question in the test was scored on a scale from 0 to 3. The responses within 10% of the exact response were scored 3, while those in the 10%-20% accuracy range were scored 2, those in the 20%-30% accuracy range were scored 1, and the responses with an inaccuracy in excess of 30% were scored 0. 3 is considered "outstanding", 2 is considered "good", 1 is considered "mediocre", and 0 is considered "poor". Furthermore, the applicability of the strategies employed by pre-service primary school teachers for the operations in the test were scored on a scale of 0 and 1. In the analysis 0 was assigned to "inapplicable strategy" while 1 stood for the "right strategy".

The scores each pre-service teacher got in the estimation skills test were then entered into SPSS package. In line with the objectives of the study, the scores were analyzed with reference to the year of study of the pre-service teachers, as well as to other variables. The percentile and frequency distribution as well as independent t-test, and ANOVA test was applied for data analysis.

RESULTS

Below, the findings are presented under three sections, dedicated to findings about the computational estimation skill levels of the pre-service primary school teachers, employment of applicable strategies in computational estimations on part of the pre-service primary school teachers, and the relationship between the pre-service primary school teachers' computational estimation skill levels and their ability to employ the applicable strategy.

Table 1. Distribution of pre-service primary school teachers' estimation skill levels in each year of education

	Level				Total (f)
Year	Poor [f (%)]	Mediocre [f (%)]	Good [f (%)]	Outstanding [f (%)]	
1	8 (18.2)	29 (65.9)	7 (15.9)	0 (0.0)	44
2	7 (14.9)	25 (53.2)	15 (31.9)	0 (0.0)	47
3	7 (11.9)	28 (47.5)	23 (39.0)	1 (1.7)	59
4	2 (3.4)	20 (33.9)	36 (61.0)	1 (1.7)	59
Total [f (%)]	24 (11.5)	102 (48.8)	81 (38.8)	2 (1.0)	209

Table 2. ANOVA test results regarding the pre-service primary school teachers' estimation skills and year of study

	Sum of squares	df	Mean square	F	Sig.	Variance
Between groups	11.04	3	3.68	8.96	.00	1st year-**4th year*** 2nd year-**4th year**
Within groups	84.16	205	.411			

Note. *Variance in favor of the year specified in **bold** font

Table 3. Applicability of the strategies employed by pre-service teachers with reference to the year of education

Year	Incorrect strategy [f (%)]	Correct strategy [f (%)]	Total (f)
1	43 (97.7)	1 (2.3)	44
2	44 (93.6)	3 (6.4)	47
3	59 (100.0)	0 (0.0)	59
4	32 (54.2)	27 (45.8)	59
Total	178 (85.2)	31 (14.8)	209

Computational Estimation Skill Levels of Pre-Service Primary School Teachers

The computational estimation skill levels of the pre-service primary school teachers who took part in the study were assessed on a scale of four levels (poor, mediocre, good, and outstanding). The analysis of the computational estimation skill levels of pre-service primary school teachers, with reference to the year of study produced the findings summarized in **Table 1**.

As **Table 1** suggests, roughly half (48.8%) of pre-service primary school teachers have "mediocre" computational estimation skills. Pre-service teachers who have "good" estimation skills comprise the second largest group, accounting for 38.8% of the sample. The pre-service teachers with "poor" skills, on the other hand, constitute a not-so-negligible group (11.5%) in contrast to only a few (1.0%) pre-service teachers who have "outstanding" computational estimation skills. In other words, the number of pre-service teachers who made estimates in the 10% accuracy range are few and far between. **Table 1** reveals that the estimation skills of 4th year pre-service primary school teachers tend to agglomerate in the "good" category (61.0%). The pre-service teachers in other years of the program, on the other hand, are more often than not in the "mediocre" level in terms of estimation skills. It is also significant that there are no pre-service teachers with "outstanding" computational estimation skills in the 1st and 2nd years of the program, while only 1.7% of 3rd and 4th year students ranked in this category.

ANOVA test was applied to find out if any statistically significant variance existed in terms of the computational estimation skill levels of pre-service primary school teachers, with reference to their year of study. The results of this analysis are presented in **Table 2**.

Table 2 reveals a statistically significant variance in terms of the year of education and the pre-service primary school teachers' computational estimation skill levels ($p<.05$). The direction of the variance was analyzed using Tukey test, leading to the conclusion that a statistically significant difference is in existence between the computational estimation skills of the 4th year pre-service primary school teachers on the one hand, and the first and 2nd year pre-service primary school teachers on the other. The variance was found to lead to a more favorable picture for the 4th year students.

Employment of Applicable Strategies in Computational Estimation by Pre-Service Primary School Teachers

The study also investigated if the pre-service primary school teachers employed the applicable strategy for operations requiring computational estimation skills, and compiled the findings in a table. The review of the applicability of the strategies employed by pre-service teachers, with reference to the year of education produced the findings presented in **Table 3**.

Table 3 presents the results of the analysis that a vast majority of pre-service primary school teachers (85.2%) employ incorrect strategies when engaging in operational estimations. Only a minority of the pre-service teachers were found to employ correct strategies when engaging in estimations of the results of operations. According to **Table 3**, rather large portion of pre-service primary school teachers in the 4th year of the program employ the correct strategy. In contrast, all 3rd year students in the pre-service primary school teacher education program had strikingly employed incorrect strategies when trying to make estimates. The applicability of the estimation strategies employed by the 1st and 2nd year students presents a comparable picture. Only a few (2.3% of 1st year students and 6.4% of 2nd year students) estimated the results using the applicable strategy.

The existence of a statistically significant relationship between the year of education, and the applicability of the strategies employed by pre-service primary school teachers when engaging in computational estimation was analyzed through ANOVA test, with results presented in **Table 4**.

Table 4. ANOVA findings regarding the applicability of the strategies employed by pre-service primary school teachers when engaging in estimation with reference to their year of education in the program

	Sum of squares	df	Mean square	F	Sig.	Variance
Between groups	7.97	3	2.66	29.56	.00	1st year-**4th year***
Within groups	18.43	205	.090			2nd year-**4th year**
						3rd year-**4th year**

Note. *Variance in favor of the year specified in **bold** font

Table 5. The relationship between the applicability of the estimation strategy employed by pre-service primary school teachers and their estimation skill levels

Strategy	N	Mean	Standard deviation	Standard error mean	t-test
Incorrect	178	1.16	.65	.049	.00
Correct	31	2.00	.26	.046	

Table 4 reveals that there is a significant variance in the applicability of the strategy employed when engaging in computational estimations, with reference to the year of education the pre-service primary school teachers is enrolled with ($p<.05$). The direction of the variance was analyzed using Tukey test, leading to the conclusion that a statistically significant difference is in existence between the computational estimation skills of the 4th year pre-service primary school teachers on the one hand, and the rest on the other. The variance presented a picture in favor of the 4th year pre-service primary school teachers.

The Relationship Between the Computational Estimation Skill Levels of and the Applicability of the Strategies Employed by Pre-Service Primary School Teachers

Finally, the existence of a relationship between the applicability of the strategies employed by pre-service primary school teachers and their accuracy in estimations was investigated, leading to the results presented in **Table 5**.

Table 5 reveals a statistically significant relationship between the computational estimation skills of and the applicability of the strategies employed by pre-service primary school teachers ($p<.05$). **Table 5** also suggests that the estimation accuracy levels of the pre-service teachers who employ the correct strategy were higher (average=2.00).

DISCUSSION AND CONCLUSIONS

The study found that pre-service primary school teachers had, more often than not, “mediocre” or “good” level of computational estimation skills. Only a few of the pre-service teachers who took part in the study exhibited “outstanding” computational estimation skills. A not negligible number of pre-service teachers, in turn, had “poor” computational estimation skills. In other words, they fail in estimation processes. Individuals with a strong number sense, who, thus, can make effective use of points of reference to facilitate the solution, and who can understand the relationship between the numbers, are deemed better in estimations (Sengul & Gulbagci-Dede, 2014; Sowder, 1984). In her study, Sengul (2013) found a very low level of number sense among pre-service primary school teachers. This is perhaps due to the fact that individuals in Turkey focus on preparing for multiple-choice tests throughout their education, and are not very familiar with exams requiring them to come up with comprehensive responses. In this context, according to Yang (2007), “to enhance number sense and estimation skills among primary school students, the first thing to do will be to try and enhance number sense skills among their pre-service teachers.” That is why it is crucial for the pre-service teachers to have good or outstanding levels of estimation skills. However, Boz-Yaman and Bulut’s (2017) study analyzing secondary school mathematics teachers’ views on estimation skills found that the teachers were unable to provide an exact definition of estimation skills, and did not have a solid grasp of the kinds and strategies of estimation skills. This observation suggests that the teachers do not attach much significance to estimation skills and strategies. Therefore, taking into account the fact that the pre-service teachers do not receive substantial support regarding the development of estimation skills through their own education, the lack of “outstanding” estimation skills could be considered a natural outcome.

Another important finding of the study is that the last (4th) year students in the pre-service teacher education program exhibited the highest level of estimation skills. The senior year pre-service primary school teachers exhibited a “good” level of computational estimation skills. Their skill levels are followed by those of the 3rd, 2nd, and the 1st year pre-service teachers, in that order, who can be noted to exhibit a “mediocre” level of estimation skills. The research also revealed that the 4th year pre-service teachers exhibit a significantly higher level of computational estimation skills compared to other years (1st and 2nd in particular). A positive progress occurs with the computational estimation skills of pre-service primary school teachers, throughout their 4-year undergraduate education. Therefore, the results of the study suggest a higher level of computational estimation skills as the pre-service primary school teacher’s progress through the program. The significant variance exhibited by the 4th year pre-service teachers, compared to the skills of those enrolled in other years of education (the 1st and 2nd years in particular) may possibly be due to the “teaching mathematics 1”, “teaching mathematics 2”, and “school experience” courses they have taken in the 3rd year (5th and 6th semesters) as well as the “teaching practice” courses they take in the first and second semesters of the 4th year. For, through the teaching mathematics courses offered in the 3rd year, the pre-service teachers get an awareness of the estimation learning outcomes involved in the mathematics-teaching program, as well as get to develop in-class activities regarding such learning outcomes. Moreover, the teaching practice course offered in their last year entail practicing at actual school environments. Bestgen et al.’s (1980) study revealed an increase in the computational estimation skills of pre-service elementary school teachers) after even a brief practice run of 10 weeks. Therefore, it is possible to argue that the courses taken by pre-service teachers, as well as the practice runs they have during their university education contribute to the development of their estimation skills. Furthermore, the experiences the pre-service teachers get during their university education, forcing them to adopt a more flexible thinking, and to develop critical thought and problem-solving skills, may also have something to do with the development of their estimation skills.

The majority of the pre-service primary school teachers were found to employ incorrect strategies when engaging in estimations requiring computational skills. The applicability of the strategies employed for estimation was found to vary significantly with reference to the year of education the pre-service teachers were enrolled in. Yet another finding was that the 4th year students distinctively employed a higher rate of accurate strategies when engaging in computational estimations. It was observed that the most common estimation strategy employed by pre-service teachers was rounding. The rather common application of rounding as the dominant computational estimation strategy is perhaps due to a lack of awareness about other strategies, and the popularity of rounding among the estimation strategies employed at schools. Reys (1986), in turn, emphasized that rounding was the only strategy shared by all teachers who have different occupational experiences, in the face of the need for computational estimation skills. In a similar vein, Pilten and Yener (2009) noted rounding and grouping as the most successful strategies among the primary school students who took part in their study.

It is evident that, at schools, neither the teachers nor the students are well aware of all estimation strategies. Therefore, as Van de Walle (2004) underlined, teaching programs should be extended to incorporate estimation strategies, to further their development in the minds of individuals. Computational estimation skills do not develop on their own; the students should be supported during the education programs, with reference to these skills, and they should be acquainted with the estimation strategies. Alajmi and Reys (2007) found that pre-service primary school mathematics teachers claimed that the estimation skills have no place in mathematics taught at school. Yet, today the teachers agree that this skill is crucial in daily life (Bozkurt & Yavasca, 2021), even though they confess not doing anything to develop them in the mathematics courses (Boz-Yaman & Bulut, 2017).

Perhaps the most important finding of the study, on the other hand, lies in the fact that the pre-service primary school teachers who employed applicable strategies had higher accuracy rates. In other words, one can forcefully argue that the pre-service teachers can have better estimation accuracy if they use the correct strategies. The findings of the study lead to the conclusion that an awareness of estimation strategies could help the pre-service teachers quickly reach approximate results. In Turkey, the revision the mathematics teaching programs underwent in 2004 included an emphasis on the development of computational estimation skills among the students, and certain estimation skills found their ways into the program (MEB, 2005). However, further revisions of the mathematics-teaching program in 2015 and 2018 removed these estimation strategies, leading to a certain de-emphasis on the learning outcomes regarding estimation skills (MEB, 2015, 2018). Yet, the teaching of estimation strategies can go a long way in helping the development of thinking skills among the students (Cilingir & Turnuklu, 2009; Reys et al., 2009). In the same vein, Goodman (1991) also underlines the need for teaching estimation skills and strategies explicitly to students. Sulak (2008) also concurs that the appropriate use of estimation strategies increases the performance of pre-service primary school teachers, and that an awareness of the strategy helps in terms of more accurate guesses. Similarly, Levine (1982) and Reys (1986) reported in their research that development of students' estimates strategies was effective in increasing the estimates skill.

Recommendations

The conclusions of the study suggest that pre-service primary school teachers could enjoy better estimation skills in case computational estimation strategies were introduced to them. Therefore, courses on mathematics to present the pre-service teachers with estimation strategies, with a view to enhancing their computational estimation skills, should be included in the teacher training programs.

The study revealed that pre-service primary school teachers did not have very strong estimation skills, but that their skill levels grew as they progressed through the program. In this context, activities to enhance pre-service primary school teachers' computational estimation skills from the earlier years of the program on should be emphasized. Such activities can help raise skilled and qualified teachers to instill a better understanding of quantities among primary school students.

Similar studies can be carried out with existing primary school teachers as well, to analyze the relationship between the estimation skills of the primary school children and those of their teachers. Finally, future studies can be based on a larger sample group to produce deeper insights.

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